AD-A125 425 SOCIOECONOMIC IMPACT ANALYSIS: COMMUNICATIONS INDUSTRY (U) ACUMENICS RESEARCH AND TECHNOLOGY INC BETHESDA MD FEB 79 FAA-APO-81-11 DOT-FA78WAI-932 1/2

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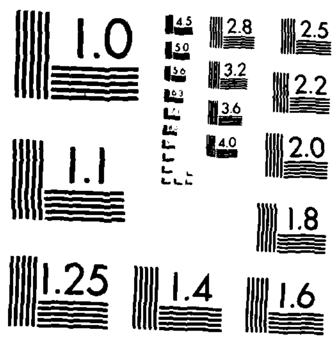

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AD A125425 (1)

Technical Report Documentation Page

1. Report No. FAA-APO-81-11 (6 of 6)	2. Government Accession No. AD-A125425	3. Recipient's Catalog No.
4. Title and Subtitle Socioeconomic Impact Analysis: Communications Industry--Summary Report		5. Report Date February 1979
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address Acumenics Research and Technology, Inc. 4340 East-West Highway Suite 808 Bethesda, Maryland 20814		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOTFA78WAI-932
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Office of Aviation Policy and Plans Washington, D. C. 20591		13. Type of Report and Period Covered
		14. Sponsoring Agency Code APO-210
15. Supplementary Notes		
16. Abstract		

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83 03 04 087

17. Key Words		18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 142	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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SUMMARY VOLUME

This volume contains the summary of a study entitled "Socioeconomic Impact Assessment: Communications Industry". The purpose of the study was to identify and assess the impacts of new communications technology on the aviation industry during the 1990 to 2020 time frame. The study includes four major phases. This vo... ~~The first~~ phase describes the aviation communications system as it existed in 1979. The second phase includes the development of three future socioeconomic scenarios as well as forecasts of relevant aviation activity under each scenario. The third phase of the effort is the forecast of communications technology. The forecast contains three major elements: 1) a forecast of communications technology without regard for future socioeconomic conditions; 2) a forecast of technology in the context of future socioeconomic scenario options; and 3) aviation communication system concepts for each socioeconomic scenario. The fourth phase of the study is the impact assessment. The impact assessment identifies and, to the extent possible, quantifies the likely consequences on future aviation communications. In the context of this effort the impacts quantified are tne effects of new technology on agency staffing requirements in the context of the three socioeconomic scenarios.

This summary volume presents briefly the results of the second, third and fourth phases of the study. The detailed aspects of each phase can be found in the appropriate study volumes. Specific aspects of each scenario are presented below. The factors presented include both economic and aviation activity factors.

SOCIOECONOMIC SCENARIOS

As noted above three socioeconomic scenarios were developed for the project: balanced growth, rapid growth and stagflation. A summary of each of the scenarios is presented below.

1. Balanced growth

   The rate and direction of technology and economic change have been explicitly constrained by society. The intent of regulating the nature and magnitude of technological growth is to minimize the untoward social and economic impacts derived from unconstrained growth. Industrial productivity increases at a slow but constant rate consistent with national policy. The population remains constant with the fertility rate being equal to replacement. Population migration results in increased growth in small cities, towns and rehabilitated inner cities. A decline in population occurs in the suburbs of metropolitan areas. The traditional adversary relationship between government and industry shifts to a cooperative arrangement. Government regulation and economic competition are combined to attain specified social goals. The market place evolves into a complex of defined markets, stratified by being completely competitive or subject to significant regulation.

2. Rapid growth

National policy marginally influences the rate and direction of technological and economic change. In general, government does not act to control the rate and direction of social change The development and diffusion of new technology is limited only by market forces. Industrial productivity increases rapidly to keep pace with the demand for intermediate and consumer goods. The national population increases with the fertility rate approaching post-World War II levels, and the replacement rate remains constant. Population migration is consistent with the patterns apparent during the 1960's - 1970's. That is, there is a net migration to the Southwest as well as continued suburban development in the East and in the Lower Great Lakes Region.

3. Stagflation

Attempts to formulate and implement a national policy for controlled economic and technological growth meet with uniform opposition from industrial interest. As such, the relationship between industry and government deteriorates. Government programs result in gerrymander regulations and laws that retard economic and technological growth. Industrial productivity decreases, unemployment increases, and inflation continues to diminish the currency. The lack of social progress increases social pressures to effect changes through increased government activity is to reverse the deregulation trend initiated in the 1970's. Previously regulated communications industries are subject to new regulation in the public interest.

Balanced Growth Scenario

Balanced Growth Economy

The balance between economic and technological growth and social needs results in modest economic growth. Industrial production increases at a slow but constant rate, consistent with national policy. Throughout the forecast period, GNP rises at an average annual rate of 2.8%. GNP expressed in 1972 dollars doubles in a twenty-four year period from $1740 trillion in 1985 to $3480 trillion by the year 2009. By the year 2020, GNP will increase 170% over the 1985 level to $4700 trillion. Disposable personal income increases at an average annual rate of 3.01% throughout the forecast period. Expressed in 1972 dollars, disposable personal income doubles in the first twenty-four year period of the forecast to $2500 trillion. By the year 2020, disposable personal income will increase 191% from $1250 trillion in 1985 to $3640 trillion. Throughout the forecast period, civilian employment experiences a steady increase at an average annual rate of 1.16%. From 1985 to the year 2020, civilian employment increases 51% from 104.3 million workers to 158 million workers. Data for the period 1985 - 2020 for each economic variable are presented in Figure 1.

As indicated previously, disposable personal income, (a measure of consumer purchasing power) and civilian employment increase steadily throughout the forecast period. The increased values of these economic variables implies that more individuals will become

FORECASTED BALANCED GROWTH: ECONOMIC VARIABLES

OBS	YR	BEMPLOY	BGNP	BDPI
1	1985	104.3	1740	1250
2	1986	105.7	1782	1296
3	1987	107.1	1822	1342
4	1988	108.5	1862	1388
5	1989	109.9	1902	1434
6	1990	111.3	1950	1480
7	1991	112.8	2025	1532
8	1992	114.2	2100	1584
9	1993	115.7	2175	1636
10	1994	117.2	2250	1688
11	1995	118.7	2325	1740
12	1996	120.3	2400	1792
13	1997	121.8	2475	1844
14	1998	123.4	2550	1896
15	1999	125.0	2625	1948
16	2000	126.6	2700	2000
17	2001	128.3	2790	2067
18	2002	129.9	2880	2134
19	2003	131.6	2970	2201
20	2004	133.4	3060	2268
21	2005	135.1	3150	2335
22	2006	136.8	3240	2402
23	2007	138.6	3330	2469
24	2008	140.4	3420	2536
25	2009	142.3	3510	2603
26	2010	144.1	3600	2670
27	2011	145.9	3710	2767
28	2012	147.8	3820	2867
29	2013	149.8	3930	2961
30	2014	150.8	4040	3155
31	2015	152.0	4150	3155
32	2016	153.2	4260	3252
33	2017	154.4	4370	3349
34	2018	155.6	4480	3446
35	2019	156.8	4590	3543
36	2020	158.0	4700	3640

OBS: Observation
YR: Year
BEMPLOY: Employment Under Balanced Growth
BGNP: Gross National Product Under Balanced Growth
BDPI: Disposable Personal Increase Under Balanced Growth

Figure 1

involved with aviation transportation. This phenomenon will occur because of the increasing number of individuals who will be able to afford air transporation services.

Aviation Industry

Throughout the forecast period, the demand for air transportation is evidenced in the size and composition of the general aviation fleet mix. The total number of aircraft in the general aviation fleet increases at an average annual rate of 1.3% throughout the forecast period. Between 1985 and the year 2020, the general aviation fleet increases by 62% from 254,000 to 413,000 aircraft. Private industry's increased demand for heavier more sophisticated aircraft accounts for the slow but increasing growth of multiengine aircraft active in the general aviation fleet. Throughout the forecast period the number of multiengine aircraft in the general aviation fleet increases at an average annual rate of 1.6%. Between 1985 and the year 2020, the number of active multiengine aircraft in the general aviation fleet increases by 82% from 28,709 to 52,174 multiengine aircraft. The increase in the number of single-engine aircraft active in the general aviation fleet is a result of a combination of industrial and public demand for air transportation. The number of single-engine aircraft, used primarily for private and instructional flying, increases at an average annual rate of 1.2% throughout the forecast period.

Between 1985 and 2020, the number of active single-engine aircraft in the general aviation fleet rises 56% from 202,481 to 315,264 single-engine aircraft. The numbers and types of aircraft projected to be active in the general aviation fleet mix is shown in Figure 2 for the three alternative scenarios. The general aviation fleet mix for the Balanced Growth Scenario is presented in Figure 3.

The effects of the projected demand levels on air transportation is reflected also in FAA workload measures. FAA provides the aviation community with several operational services including the following two activities: air traffic control at FAA towered airports and traffic surveillance and separation at Air Route Traffic Control Centers. The need for FAA operational services will increase as a result of growth in aviation activity. Total aircraft operations at FAA towered airports are projected to increase at an average annual rate of 1.9% throughout the forecast period. Between 1985 and 2020, total aircraft operations at FAA towered airports increase 101% from 83 million to 166 million aircraft operations. Itinerant aircraft operations rise at an average annual rate of 1.7% throughout the forecast period. Between 1985 and the year 2020, itinerant aircraft operations at FAA towered airports increase 86% from 55.9 million operations to 104.3 million operations. The increase in itinerant operations reflects both the increases in utilization of general aviation by business and the increase in demand for air carrier services by

GENERAL AVIATION (GA) FLEET CHARACTERISTICS

OBS	YR	T	BTOTGA	RTOTGA	STOTGA	BSEGA	RSEGA	SSEGA	BMEGA	RMEGA	SMEGA	BOGA	ROGA	SOGA
1	1985	10	254.871	264.975	248.542	202.481	209.826	197.622	28.7087	29.8456	25.4538	23.6814	25.3029	25.4656
2	1936	11	264.042	277.280	254.167	209.235	218.959	201.760	29.6851	31.0952	26.0600	25.1216	27.2252	26.3472
3	1987	12	273.008	289.800	259.167	215.809	228.239	205.428	30.6577	32.3785	26.6662	26.5413	29.1826	27.0732
4	1988	13	281.740	302.508	263.587	222.183	237.646	208.662	31.6243	33.6949	27.2724	27.9323	31.1667	27.6522
5	1989	14	290.213	315.374	267.474	228.343	247.162	211.501	32.5826	35.0438	27.8786	29.2872	33.1681	28.0943
6	1990	15	298.404	328.367	270.879	234.274	256.766	213.984	33.5305	36.4241	28.4848	30.5992	35.1774	28.4105
7	1991	16	306.294	341.455	273.850	239.966	266.436	216.147	34.4658	37.8349	29.0910	31.8624	37.1844	28.6123
8	1992	17	313.869	354.605	276.435	245.411	276.151	218.026	35.3867	39.2751	29.6972	33.0718	39.1790	28.7111
9	1993	18	321.118	367.781	278.676	250.604	285.887	219.655	36.2912	40.7432	30.3034	34.2234	41.1508	28.7180
10	1994	19	328.033	380.950	280.616	255.541	295.623	221.063	37.1776	42.2379	30.9096	35.3140	43.0896	28.6434
11	1995	20	334.610	394.079	282.290	260.224	305.336	222.278	38.0445	43.7575	31.5158	36.3416	44.9854	28.4968
12	1996	21	340.847	407.132	283.733	264.652	315.003	223.324	38.8905	45.3004	32.1220	37.3047	46.8285	28.2873
13	1997	22	346.747	420.077	284.975	268.830	324.602	224.224	39.7143	46.8648	32.7282	38.2028	48.6095	28.0227
14	1998	23	352.313	432.882	286.042	272.762	334.113	224.997	40.5149	48.4487	33.3344	39.0362	50.3200	27.7101
15	1999	24	357.551	445.516	286.957	276.454	343.514	225.661	41.2914	50.0500	33.9406	39.8059	51.9520	27.3561
16	2000	25	362.471	457.952	287.742	279.915	352.787	226.229	42.0431	51.6666	34.5468	40.5131	53.4984	26.9661
17	2001	26	367.081	470.161	288.415	283.151	361.912	226.717	42.7694	53.2963	35.1530	41.1600	54.9529	26.5451
18	2002	27	371.392	482.119	288.990	286.173	370.872	227.134	43.4700	54.9367	35.7592	41.7488	56.3103	26.0975
19	2003	28	375.416	493.803	289.483	288.989	379.652	227.491	44.1445	56.5855	36.3654	42.2822	57.5663	25.6269
20	2004	29	379.166	505.194	289.904	291.610	388.236	227.796	44.7929	58.2402	36.9716	42.7631	58.7176	25.1365
21	2005	30	382.655	516.274	290.264	294.045	396.614	228.057	45.4152	59.8984	37.5778	43.1945	59.7620	24.6293
22	2006	31	385.896	527.028	290.571	296.305	404.772	228.280	46.0115	61.5576	38.1840	43.5796	60.6981	24.1076
23	2007	32	388.902	537.442	290.834	298.399	412.701	228.470	46.5820	63.2153	38.7902	43.9215	61.5256	23.5735
24	2008	33	391.687	547.508	291.058	300.337	420.394	228.633	47.1271	64.8690	39.3964	44.2233	62.2450	23.0289
25	2009	34	394.265	557.217	291.249	302.129	427.843	228.771	47.6473	66.5163	40.0026	44.4883	62.8579	22.4751
26	2010	35	396.647	566.564	291.412	303.785	435.043	228.890	48.1430	68.1547	40.6088	44.7194	63.3663	21.9137
27	2011	36	398.847	575.547	291.552	305.312	441.992	228.991	48.6148	69.7819	41.2150	44.9196	63.7732	21.3456
28	2012	37	400.876	584.163	291.670	306.721	448.685	229.077	49.0634	71.3956	41.8212	45.0917	64.0821	20.7719
29	2013	38	402.746	592.414	291.772	308.018	455.123	229.151	49.4893	72.9935	42.4274	45.2382	64.2971	20.1934
30	2014	39	404.468	600.302	291.858	309.213	461.306	229.214	49.8934	74.5736	43.0336	45.3617	64.4225	19.6108
31	2015	40	406.053	607.832	291.932	310.312	467.235	229.267	50.2763	76.1337	43.6398	45.4646	64.4633	19.0247
32	2016	41	407.510	615.009	291.995	311.323	472.912	229.313	50.6389	77.6720	44.2460	45.5490	64.4246	18.4357
33	2017	42	408.850	621.840	292.048	312.251	478.341	229.352	50.9819	79.1867	44.8522	45.6169	64.3117	17.8441
34	2018	43	410.080	628.333	292.094	313.104	483.526	229.385	51.3061	80.6761	45.4584	45.6702	64.1302	17.2503
35	2019	44	411.210	634.496	292.133	313.887	488.472	229.414	51.6122	82.1386	46.0646	45.7106	63.8854	16.6547
36	2020	45	412.246	640.340	292.166	314.605	493.184	229.438	51.9011	83.5728	46.6708	45.7397	63.5829	16.0575
37	2021	46	413.196	645.874	292.195	315.264	497.668	229.459	52.1735	84.9775	47.2770	45.7588	63.2283	15.4590

B: Balanced Growth
R: Rapid Growth
S: Stagflation
TOTGA: Total GA Fleet
SEGA: Single-Engine GA Fleet
MEGA: Multiengine GA Fleet
OGA: Other GA Fleet

Figure 2

ACUMENICS

G.A. AIRCRAFT-BALANCED GROWTH

PLOT OF BTOTGA*YR   SYMBOL USED IS T
PLOT OF BSEGA*YR   SYMBOL USED IS S
PLOT OF BMEGA*YR   SYMBOL USED IS M
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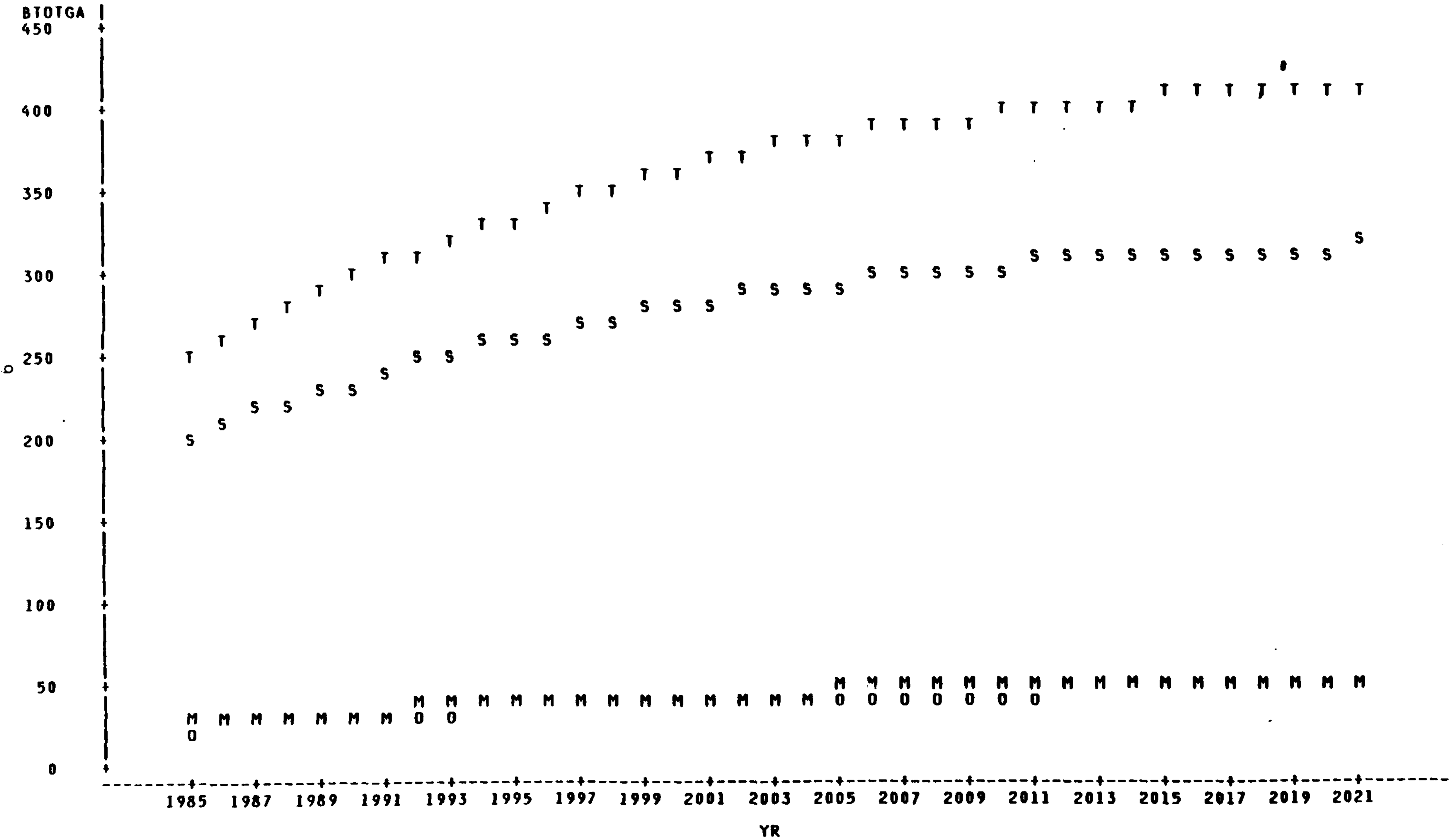


Figure 3

the general public. Local aircraft operations increase at an average annual rate of 2.3% throughout the forecast period. Between 1985 and the year 2020, local aircraft operations performed at FAA towered airports increase 131% from 27 million to 62 million. The increase in local aircraft operations derives from an increase in pilot instruction which will in turn create more air traffic after students become licensed pilots. The complete tabulations for FAA towered airport workload measures are given in Figure 4. The measures displayed graphically in Figure 5 are the FAA towered airport workload measures for the Balanced Growth Scenario.

The growth in the number of aircraft handled by the Air Route Traffic Control Centers increases at an average annual rate of 1.7% throughout the forecast period. From 1985 to 2020, total IFR aircraft handled by Air Route Traffic Centers increases 88% from 36 million to 68 million aircraft. The increases in operations at Air Route Traffic Control Centers will be a result of increases in general aviation traffic associated with increases in pilot capabilities and an increased use of larger more sophisticated aircraft. The complete tabulations of enroute center work measures are given in Figure 6. The enroute work measures for the Balanced Growth Scenario are displaved graphicallv in Figure 7.

FAA TOWERED AIRPORT WORKLOAD MEASURES

OBS	YR	T	BTOPS	RTOPS	STOPS	BITOPS	RITOPS	SITOPS	BLOPS	RLOPS	SLOPS
1	1985	15	83.012	96.249	80.121	55.927	67.316	53.7079	27.0859	28.9331	26.4126
2	1986	16	85.412	99.862	81.810	57.714	70.102	54.9736	27.6973	29.7598	26.8366
3	1987	17	87.835	103.474	83.450	59.503	72.888	56.1922	28.3314	30.5865	27.2582
4	1988	18	90.279	107.087	85.039	61.290	75.674	57.3623	28.9894	31.4132	27.6771
5	1989	19	92.744	110.699	86.576	63.071	78.459	58.4831	29.6722	32.2399	28.0929
6	1990	20	95.225	114.312	88.059	64.844	81.245	59.5539	30.3806	33.0666	28.5050
7	1991	21	97.720	117.924	89.487	66.605	84.031	60.5745	31.1153	33.8933	28.9129
8	1992	22	100.227	121.537	90.861	68.350	86.817	61.5452	31.8769	34.7200	29.3161
9	1993	23	102.743	125.149	92.180	70.078	89.603	62.4663	32.6658	35.5467	29.7139
10	1994	24	105.266	128.762	93.444	71.784	92.388	63.3387	33.4822	36.3734	30.1058
11	1995	25	107.792	132.374	94.654	73.466	95.174	64.1634	34.3261	37.2001	30.4911
12	1996	26	110.320	135.987	95.811	75.122	97.960	64.9415	35.1975	38.0268	30.8692
13	1997	27	112.845	139.599	96.914	76.750	100.746	65.6744	36.0960	38.8535	31.2397
14	1998	28	115.367	143.212	97.966	78.346	103.532	66.3636	37.0210	39.6802	31.6019
15	1999	29	117.881	146.824	98.966	79.909	106.317	67.0108	37.9720	40.5069	31.9555
16	2000	30	120.385	150.437	99.918	81.437	109.103	67.6176	38.9481	41.3336	32.3000
17	2001	31	122.877	154.049	100.821	82.928	111.889	68.1859	39.9483	42.1603	32.6350
18	2002	32	125.353	157.662	101.678	84.382	114.675	68.7173	40.9713	42.9870	32.9603
19	2003	33	127.812	161.274	102.489	85.796	117.461	69.2137	42.0159	43.8137	33.2755
20	2004	34	130.251	164.887	103.258	87.171	120.246	69.6769	43.0806	44.6404	33.5806
21	2005	35	132.668	168.499	103.984	88.504	123.032	70.1087	44.1639	45.4671	33.8752
22	2006	36	135.060	172.112	104.670	89.796	125.818	70.5109	45.2640	46.2938	34.1595
23	2007	37	137.426	175.724	105.318	91.046	128.604	70.8850	46.3792	47.1205	34.4332
24	2008	38	139.762	179.337	105.929	92.254	131.390	71.2328	47.5077	47.9472	34.6965
25	2009	39	142.068	182.949	106.505	93.420	134.175	71.5560	48.6475	48.7739	34.9494
26	2010	40	144.341	186.562	107.048	94.544	136.961	71.8559	49.7968	49.6006	35.1919
27	2011	41	146.579	190.174	107.558	95.625	139.747	72.1342	50.9536	50.4273	35.4242
28	2012	42	148.782	193.787	108.039	96.666	142.533	72.3922	52.1159	51.2540	35.6466
29	2013	43	150.947	197.399	108.490	97.665	145.319	72.6313	53.2817	52.0807	35.8590
30	2014	44	153.073	201.012	108.915	98.624	148.104	72.8527	54.4491	52.9074	36.0619
31	2015	45	155.160	204.624	109.313	99.543	150.890	73.0576	55.6163	53.7341	36.2554
32	2016	46	157.205	208.237	109.687	100.424	153.676	73.2472	56.7813	54.5608	36.4397
33	2017	47	159.209	211.849	110.038	101.266	156.462	73.4226	57.9423	55.3875	36.6152
34	2018	48	161.169	215.462	110.367	102.072	159.248	73.5847	59.0975	56.2142	36.7821
35	2019	49	163.086	219.074	110.675	102.841	162.033	73.7346	60.2454	57.0409	36.9407
36	2020	50	164.959	222.687	110.964	103.575	164.819	73.8730	61.3843	57.8676	37.0913
37	2021	51	166.788	226.299	111.235	104.275	167.605	74.0009	62.5127	58.6943	37.2342

B: Balanced Growth
R: Rapid Growth
S: Stagflation
TOPS: Total Operations
ITOPS: ITINERANT OPERATIONS

Figure 4

BALANCED GROWTH-OPERATIONS

PLOT OF BTOPS*YR   SYMBOL USED IS T
PLOT OF BITOPS*YR   SYMBOL USED IS I
PLOT OF BLOPS*YR   SYMBOL USED IS L

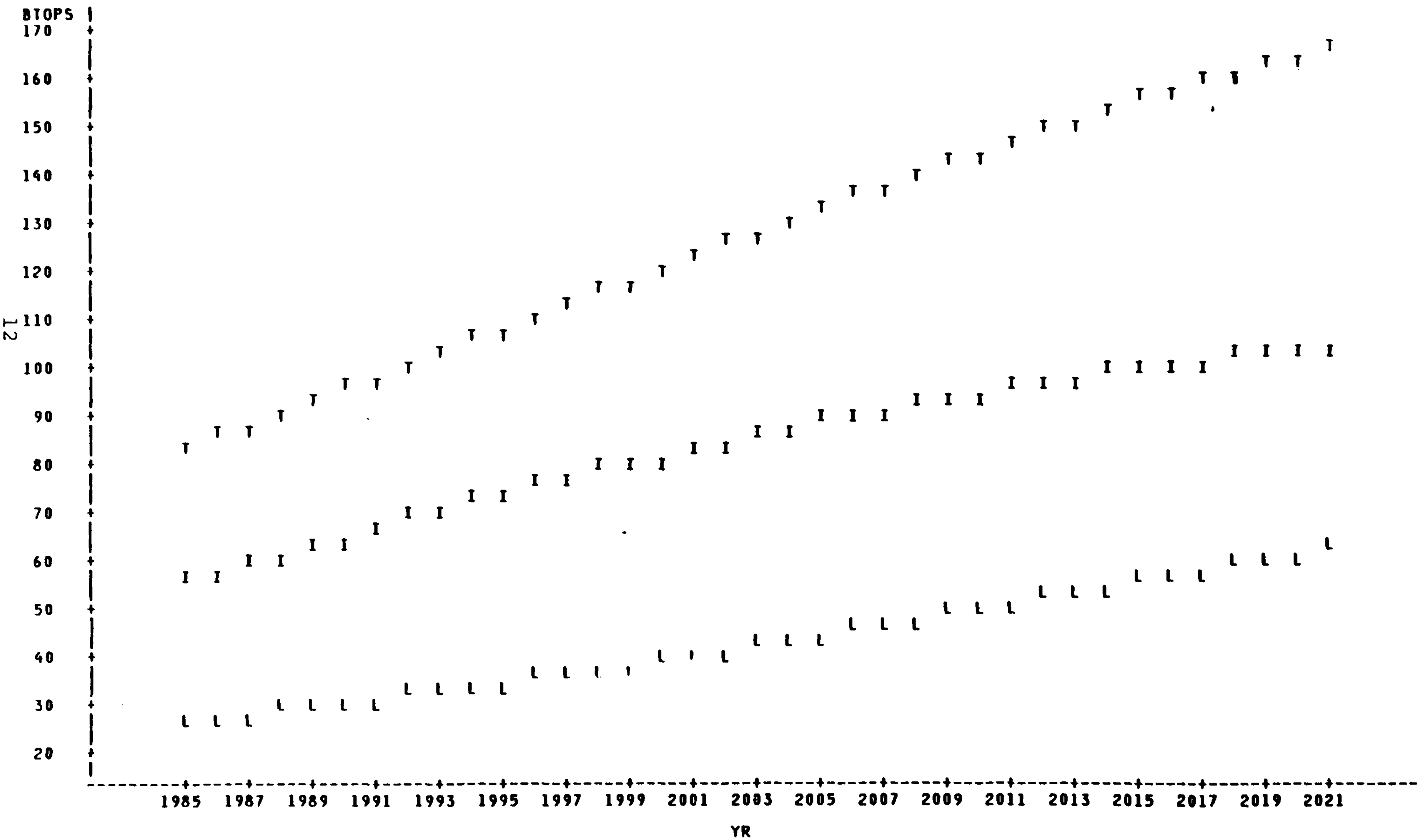


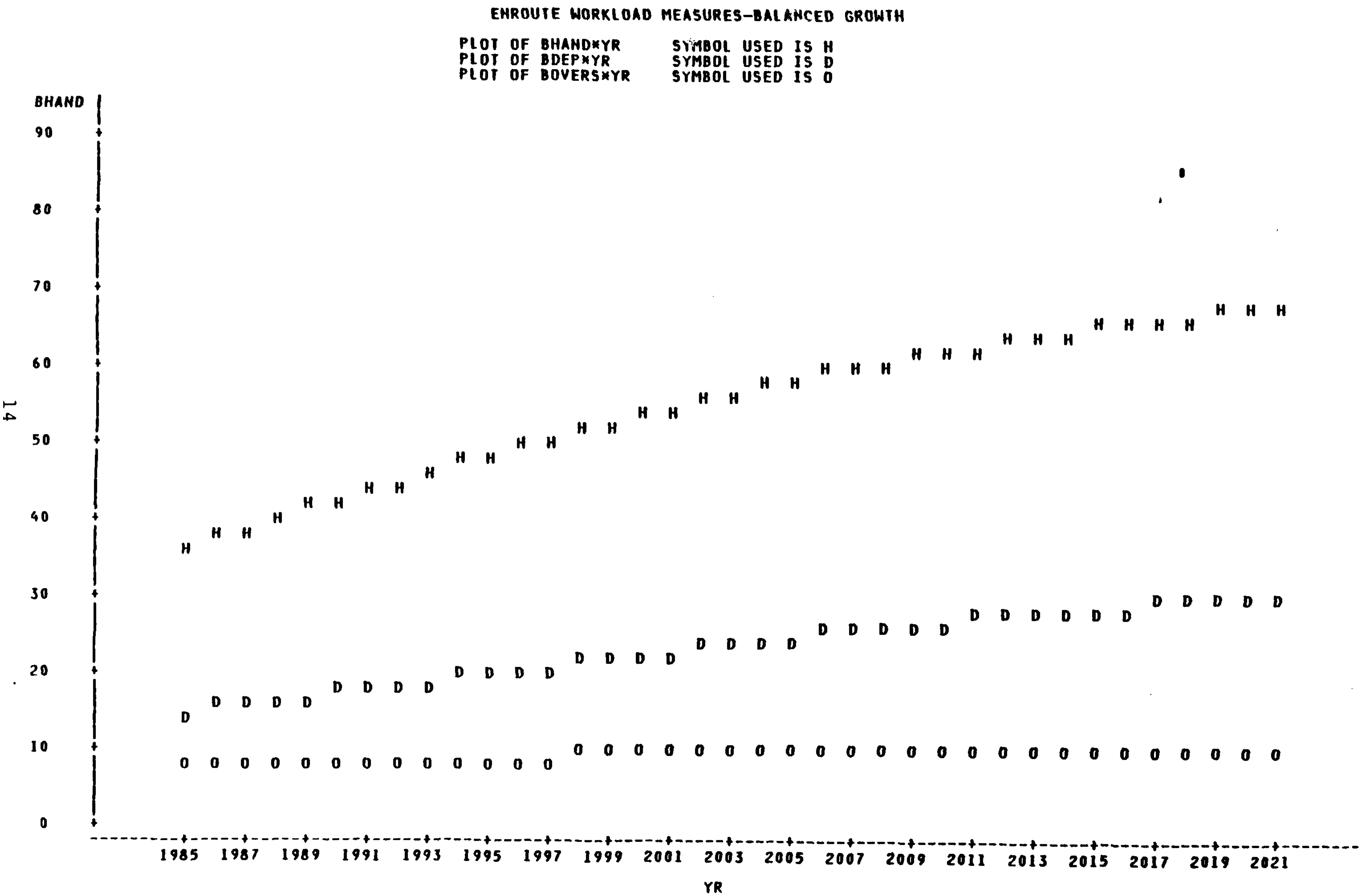
Figure 5

ENROUTE CENTER WORKLOAD MEASURES

OBS	YR	T	BHAND	RHAND	SHAND	BDEP	RDEP	SDEP	BOVERS	ROVERS	SOVERS
1	1985	15	36.3731	43.118	34.8851	14.4762	17.4614	13.8709	7.3637	7.6117	7.16895
2	1986	16	37.5891	44.984	35.7551	15.0014	18.2586	14.2429	7.5306	7.8277	7.29822
3	1987	17	38.8057	46.851	36.5936	15.5312	19.0558	14.6032	7.6924	8.0437	7.42035
4	1988	18	40.0201	48.718	37.3994	16.0645	19.8530	14.9511	7.8487	8.2597	7.53547
5	1989	19	41.2300	50.585	38.1716	16.6005	20.6502	15.2861	7.9995	8.4757	7.64371
6	1990	20	42.4329	52.451	38.9098	17.1381	21.4474	15.6078	8.1445	8.6917	7.74527
7	1991	21	43.6263	54.318	39.6137	17.6762	22.2446	15.9159	8.2839	8.9077	7.84037
8	1992	22	44.8079	56.185	40.2833	18.2139	23.0418	16.2103	8.4174	9.1237	7.92923
9	1993	23	45.9756	58.051	40.916[illegible]	18.7502	23.8390	16.4908	8.5452	9.3397	8.01213
10	1994	24	47.1271	59.918	41.5205	19.2840	24.6362	16.7577	8.6671	9.5557	8.08933
11	1995	25	48.2605	61.785	42.0892	19.8144	25.4334	17.0108	8.7834	9.7717	8.16111
12	1996	26	49.3739	63.651	42.6257	20.3403	26.2306	17.2506	8.8941	9.9877	8.22776
13	1997	27	50.4656	65.518	43.1307	20.8608	27.0278	17.4772	8.9992	10.2037	8.28955
14	1998	28	51.5340	67.385	43.6054	21.3752	27.8250	17.6909	9.0990	10.4197	8.34677
15	1999	29	52.5777	69.252	44.0509	21.8824	28.6222	17.8922	9.1935	10.6357	8.39970
16	2000	30	53.5956	71.118	44.4683	22.3817	29.4194	18.0815	9.2829	10.8517	8.44861
17	2001	31	54.5864	72.985	44.8588	22.8724	30.2166	18.2592	9.3674	11.0677	8.49375
18	2002	32	55.5493	74.852	45.2237	23.3538	31.0138	18.4257	9.4471	11.2837	8.53538
19	2003	33	56.4836	76.718	45.5643	23.8252	31.8110	18.5816	9.5223	11.4997	8.57374
20	2004	34	57.3886	78.585	45.8817	24.2861	32.6082	18.7274	9.5930	11.7157	8.60906
21	2005	35	58.2640	80.452	46.1773	24.7360	33.4054	18.8636	9.6596	11.9317	8.64155
22	2006	36	59.1094	82.318	46.4523	25.1744	34.2026	18.9905	9.7222	12.1477	8.67143
23	2007	37	59.9247	84.185	46.7078	25.6010	34.9998	19.1089	9.7810	12.3637	8.69888
24	2008	38	60.7099	86.052	46.9451	26.0155	35.7970	19.2190	9.8361	12.5797	8.72410
25	2009	39	61.4650	87.919	47.1652	26.4176	36.5942	19.3215	9.8878	12.7957	8.74724
26	2010	40	62.1904	89.785	47.3693	26.8072	37.3914	19.4167	9.9363	13.0117	8.76848
27	2011	41	62.8862	91.652	47.5583	27.1841	38.1886	19.5051	9.9816	13.2277	8.78795
28	2012	42	63.5529	93.519	47.7334	27.5482	38.9858	19.5872	10.0240	13.4437	8.80580
29	2013	43	64.1911	95.385	47.8954	27.8996	39.7830	19.6633	10.0637	13.6597	8.82216
30	2014	44	64.8012	97.252	48.0452	28.2382	40.5802	19.7338	10.1007	13.8757	8.83714
31	2015	45	65.3840	99.119	48.1836	28.5641	41.3774	19.7992	10.1353	14.0917	8.85087
32	2016	46	65.9400	100.985	48.3115	28.8775	42.1746	19.8596	10.1676	14.3077	8.86343
33	2017	47	66.4699	102.852	48.4297	29.1784	42.9718	19.9156	10.1978	14.5237	8.87494
34	2018	48	66.9747	104.719	48.5387	29.4671	43.7690	19.9673	10.2259	14.7397	8.88546
35	2019	49	67.4550	106.586	48.6393	29.7438	44.5662	20.0152	10.2521	14.9557	8.89509
36	2020	50	67.9117	108.452	48.7322	30.0088	45.3634	20.0594	10.2766	15.1717	8.90390
37	2021	51	68.3455	110.319	48.8178	30.2622	46.1606	20.1002	10.2993	15.3877	8.91195

B: Balanced Growth
R: Rapid Growth
S: Stagflation
HAND: Aircraft Handled
DEP: Departures Handled
OVERS: Overs Handled

Figure 6


ENROUTE WORKLOAD MEASURES-BALANCED GROWTH
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PLOT OF BOVERS*YR SYMBOL USED IS 0
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1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021
YR

Figure 7

Rapid Growth Scenario

Rapid Growth Economy

The result of rapid economic and technological growth is reflected in the GNP statistics for this scenario. Throughout the forecast period, GNP will rise at an average annual rate of 4.2%. Between 1985 and the year 2020, GNP expressed in 1972 dollars increases 342% from $1900 trillion to $8400 trillion. The average annual rate of increase for Disposable Personal Income is approximately the same as the rate of growth in the GNP for the same forecast period. However, Disposable Personal Income (also expressed in 1972 dollars) increases 345% from $1310 trillion in 1985 to $5830 trillion in the year 2020. Civilian Employment rises steadily at an average annual rate of 1% throughout the forecast period. Between 1985 and the year 2020, the civilian workforce is projected to increase 55% from 105.7 million workers to 163.9 million workers. The values of the economic variables for each year in the 1985-2020 period are included in Figure 8.

The GNP statistics indicate that industrial production increases constantly throughout the forecast period. An increase in industrial activity indicates that there will be a great demand for general aviation transportation. The GNP measures in this forecast also indicate that substantial levels of capital will be available to develop technology in the aviation and communications industries. The projected annual rate of increase for dis-

FORECASTED RAPID GROWTH: ECONOMIC VARIABLES

OBS	YR	REMPLOY	RGNP	RDPI
1	1985	105.7	1900	1310
2	1986	108.3	1980	1372
3	1987	111.0	2060	1434
4	1988	113.7	2140	1496
5	1989	116.4	2220	1558
6	1990	119.0	2300	1620
7	1991	119.9	2420	1702
8	1992	120.8	2540	1784
9	1993	121.7	2660	1866
10	1994	122.6	2780	1948
11	1995	123.5	2900	2030
12	1996	124.4	3020	2112
13	1997	125.3	3140	2194
14	1998	126.2	3260	2276
15	1999	127.1	3380	2358
16	2000	128.0	3500	2440
17	2001	129.8	3700	2579
18	2002	131.6	3900	2718
19	2003	133.4	4100	2857
20	2004	135.2	4300	2996
21	2005	137.0	4500	3135
22	2006	138.8	4700	3274
23	2007	140.6	4900	3413
24	2008	142.4	5100	3552
25	2009	144.2	5300	3691
26	2010	146.0	5500	3830
27	2011	147.2	5790	4030
28	2012	148.4	6080	4230
29	2013	149.6	6370	4430
30	2014	151.7	6660	4830
31	2015	153.7	6950	4830
32	2016	155.7	7240	5030
33	2017	157.7	7530	5230
34	2018	159.7	7820	5430
35	2019	161.9	8110	5630
36	2020	163.9	8400	5830

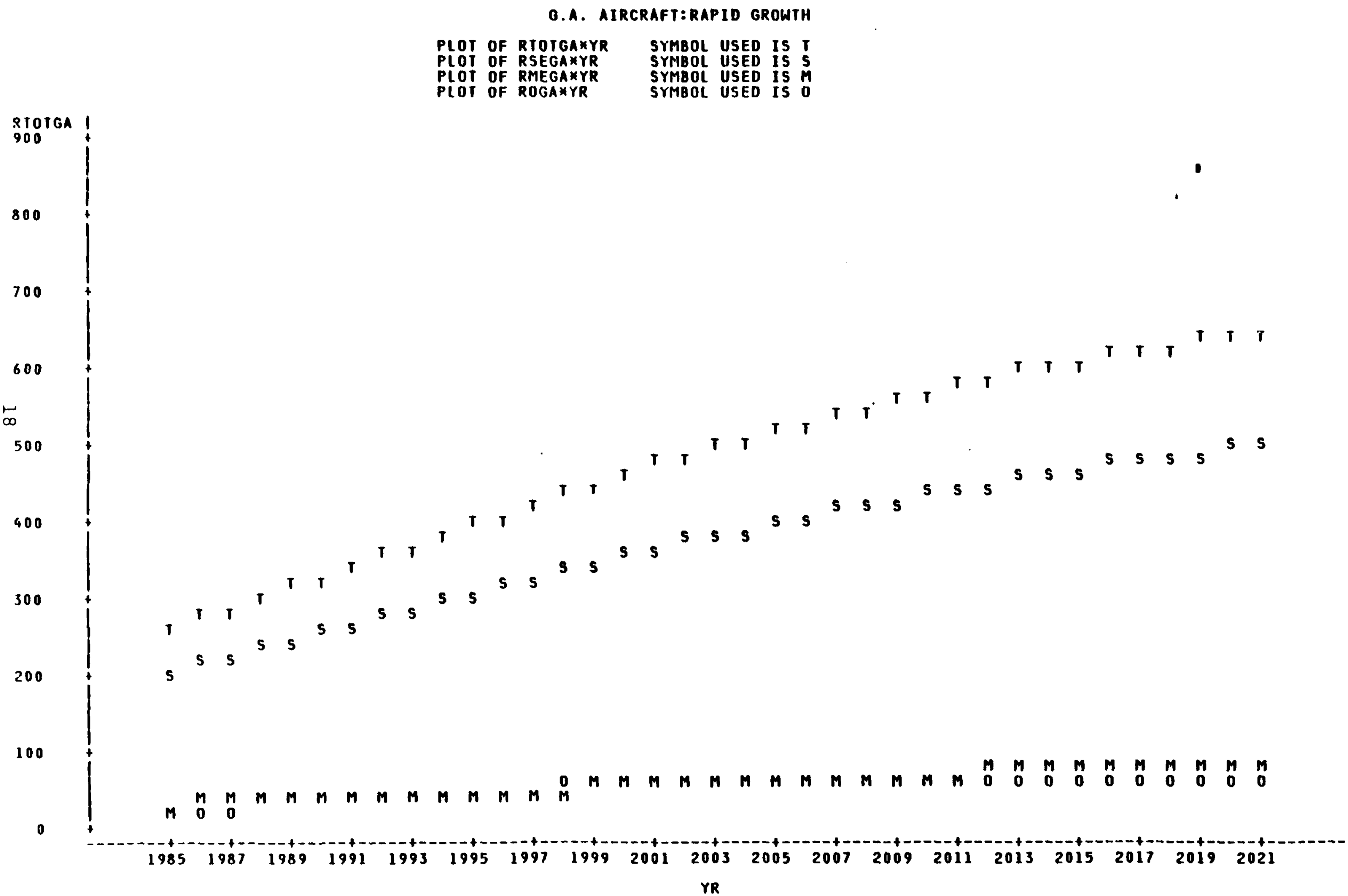
R: Rapid Growth
Employ: Employment
GNP: Gross National Product
DPI: Disposable Personal Increase

Figure 8

posable personal income and civilian employment suggest that an increasing amount of individuals will have available the resources necessary to utilize air transportation.

Aviation Industry

The size and composition of the general aviation fleet reflects society's demand for air transportation. The total general aviation fleet rises at an average annual rate of 2.4% throughout the forecast period. By the year 2020, the total general aviation fleet rises 144% from 264,975 aircraft to 645,874 aircraft. Throughout the forecast period, the number of multiengine aircraft active in the general aviation fleet increases at an average annual rate of 2.9%. Between 1985 and the year 2020, the number of multiengine aircraft active in the general aviation fleet increases 185% from 298,456 aircraft to 849,775 aircraft. The increase in multiengine aircraft activity is attributed to the increasing utilization of general aviation by private industry. Single-engine aircraft active in the general aviation fleet rises at an average annual rate of 2.4%. By the year 2020, active single-engine aircraft in the general aviation fleet increase 137% from 209,826 to 497,668 single-engine aircraft. The increase in the utilization of single-engine aircraft reflects an increase in instructional and recreational flying. The general aviation fleet mix for the Rapid Growth Scenario is shown graphically in Figure 9. (The complete tabulation for the general aviation fleet is shown in Figure 2).


G.A. AIRCRAFT:RAPID GROWTH
PLOT OF RTOTGA*YR SYMBOL USED IS T
PLOT OF RSEGA*YR SYMBOL USED IS S
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1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021
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Figure 9

As noted previously in the Balanced Growth Scenario presentation, an increase in demand for air transportation results in an increase of FAA operational services. In the Rapid Growth Scenario, the increasing demand for air transportation further intensifies the utilization of FAA operational services. Total aircraft operations at FAA towered airports is projected to increase at an average annual rate of 2.3% throughout the forecast period. Between 1985 and the year 2020, total aircraft operations at airports with FAA towers are forecast to increase by 136% from 96 million to 226.3 million operations. Itinerant aircraft operations at FAA towered airports rises at an average annual rate of 2.5%. Between 1985 and the year 2020, itinerant aircraft operations at FAA towered airports increase 149% from 67.3 million operations to 167.6 million aircraft operations.

The increasing utilization of general aviation services by industry and the increasing demand for air carrier services by the general public will account for the increasing itinerant aircraft operations at FAA towered airports. Throughout the forecast period, local aircraft operations at FAA towered airports, increases at an average annual rate of 1.9%. By the year 2020, local aircraft operations will increase 103% beyond the 1985 figure of 28.9 million to 58.7 million local aircraft operations. The steady increase in local aircraft operations at FAA towered airports implies that the number of pilots undergoing flight training will increase throughout

the forecast period. The complete tabulations for FAA towered workload measures are given in Figure 4. Displayed graphically in Figure 10, are the FAA towered airport workload measures for the Rapid Growth Scenario.

The growth in the number of aircraft handled by Air Route Traffic Control Centers reflects increases in general aviation traffic associated with increases in pilots capable of IFR flights. The number of aircraft handled by Air Route Traffic Control Centers increases at an average annual rate of 2.6%. Between 1985 and the year 2020, IFR aircraft handled by Air Route Traffic Control Centers increases 156% from 43 million to 110.3 million aircraft. The complete tabulations of enroute work measures are given in Figure 6. Displayed graphically in Figure 11 are the enroute measures for this scenario.

Stagflation Scenario

Stagflation Economy

Throughout the forecast period, GNP and Disposable Personal Income both rise at an average annual rate of 1.5%. Between 1985 and the year 2020, GNP expressed in 1972 dollars increases 66% from $1605.1 trillion to $2662.9 trillion. In the forecast period from 1985 to 2020, Disposable Personal Income increases 69% from $1114.6 trillion to $1876.8 trillion. During the forecast period, Civilian Employment experiences a low average annual growth rate of 0.48%. Between 1985 and the year 2020, Civilian Employment increases only by 19% from 103.7 million workers to 123 million workers. The tabulations of the economic variables are given in Table 6.

RAPID GROWTH: OPERATIONS, TOWERED AIRPORTS

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PLOT OF RITOPS*YR SYMBOL USED IS I
PLOT OF RLOPS*YR SYMBOL USED IS L

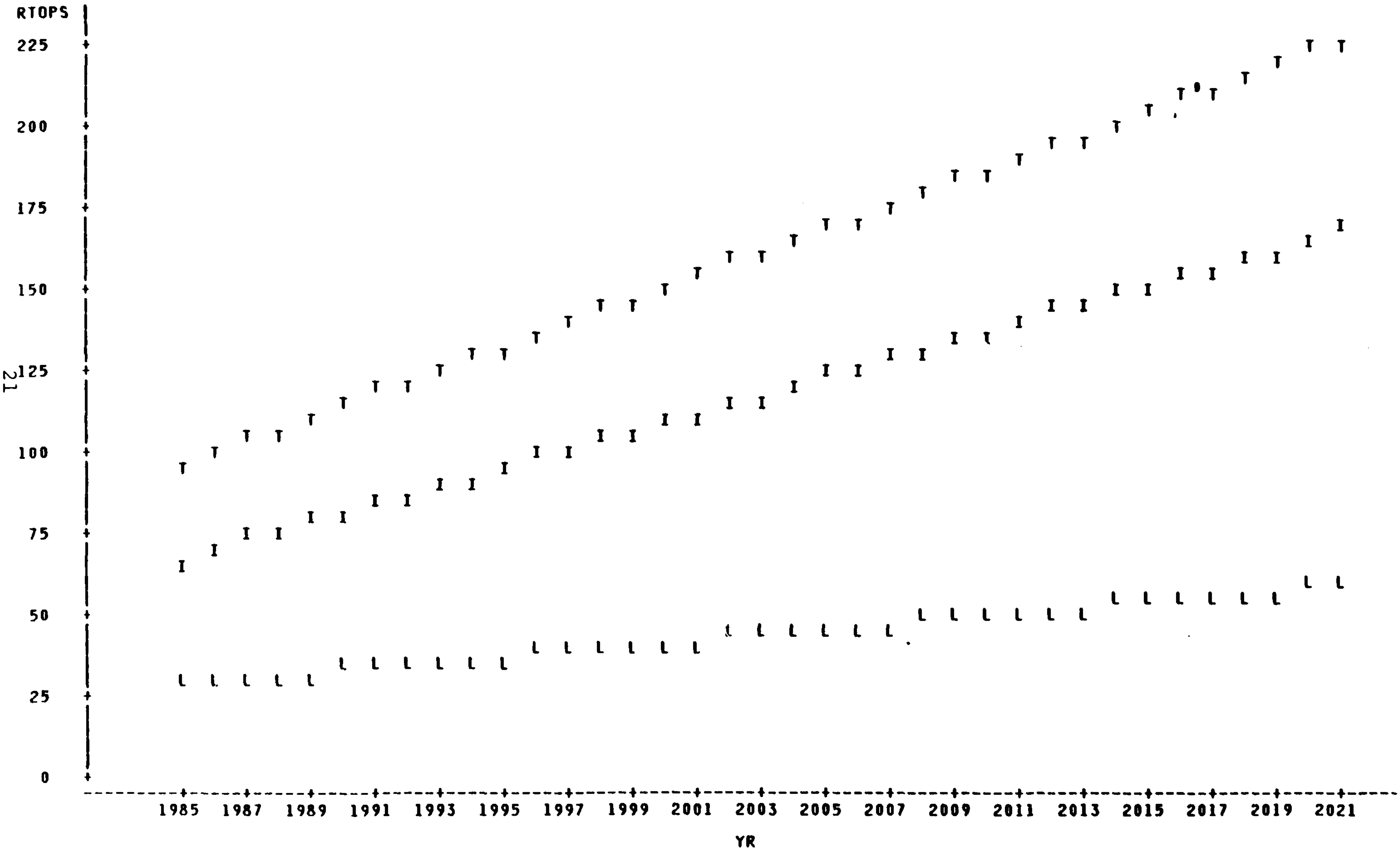

Figure 10

ENROUTE WORKLOAD MEASURES: RAPID GROWTH

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PLOT OF RDEP*YR   SYMBOL USED IS D
PLOT OF ROVERS*YR   SYMBOL USED IS O

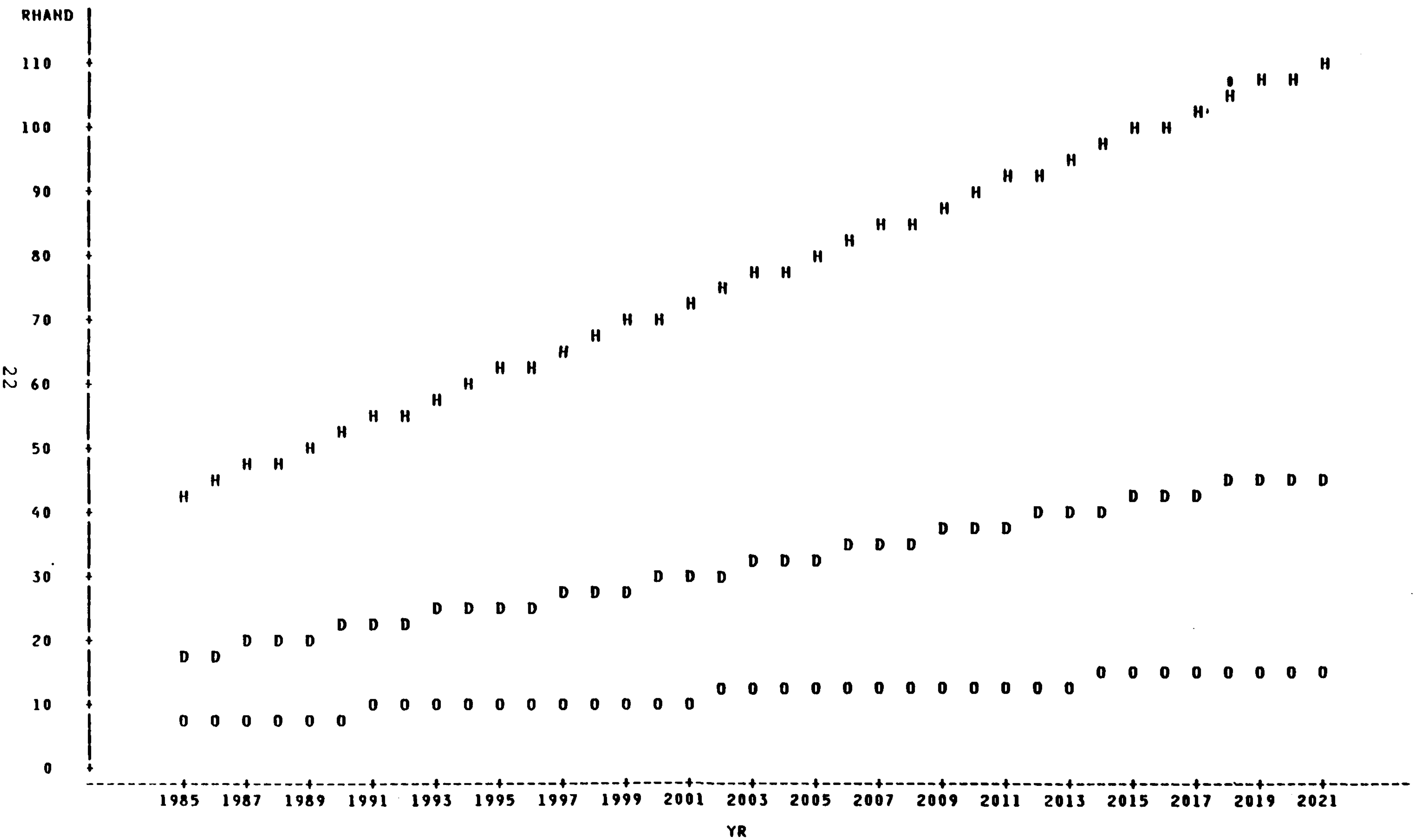


Figure 11

FORECASTED STAGFLATION ECONOMIC VARIABLES

OBS	YR	SEMPLOY	SGNP	SDPI
1	1985	103.7	1605.1	1114.6
2	1986	104.3	1629.2	1131.3
3	1987	105.0	1653.6	1148.3
4	1988	105.7	1678.4	1165.5
5	1989	106.4	1703.6	1183.0
6	1990	107.0	1729.2	1200.7
7	1991	107.6	1755.1	1218.7
8	1992	108.2	1781.4	1237.0
9	1993	108.8	1808.2	1255.6
10	1994	109.4	1835.3	1274.4
11	1995	110.0	1862.8	1293.5
12	1996	110.6	1890.8	1312.9
13	1997	111.2	1919.1	1332.6
14	1998	111.8	1947.9	1352.6
15	1999	112.4	1977.1	1372.9
16	2000	113.0	2006.8	1393.5
17	2001	113.5	2036.9	1414.4
18	2002	114.0	2067.4	1435.6
19	2003	114.5	2098.4	1457.1
20	2004	115.0	2129.9	1479.0
21	2005	115.5	2161.9	1501.2
22	2006	116.0	2194.3	1523.7
23	2007	116.5	2227.2	1546.5
24	2008	117.0	2260.6	1569.7
25	2009	117.5	2294.5	1593.3
26	2010	118.0	2328.9	1617.2
27	2011	118.5	2363.9	1641.4
28	2012	119.0	2399.3	1666.1
29	2013	119.5	2435.3	1691.1
30	2014	120.0	2508.9	1742.2
31	2015	120.5	2508.9	1742.2
32	2016	121.0	2546.6	1768.3
33	2017	121.5	2584.8	1794.8
34	2018	122.0	2623.5	1821.7
35	2019	122.5	2662.9	1849.1
36	2020	123.0	2702.8	1876.8

S: Stagflation
Employ: Employment
GNP: Gross National Product
DPI: Disposable Personal Increase

Figure 12

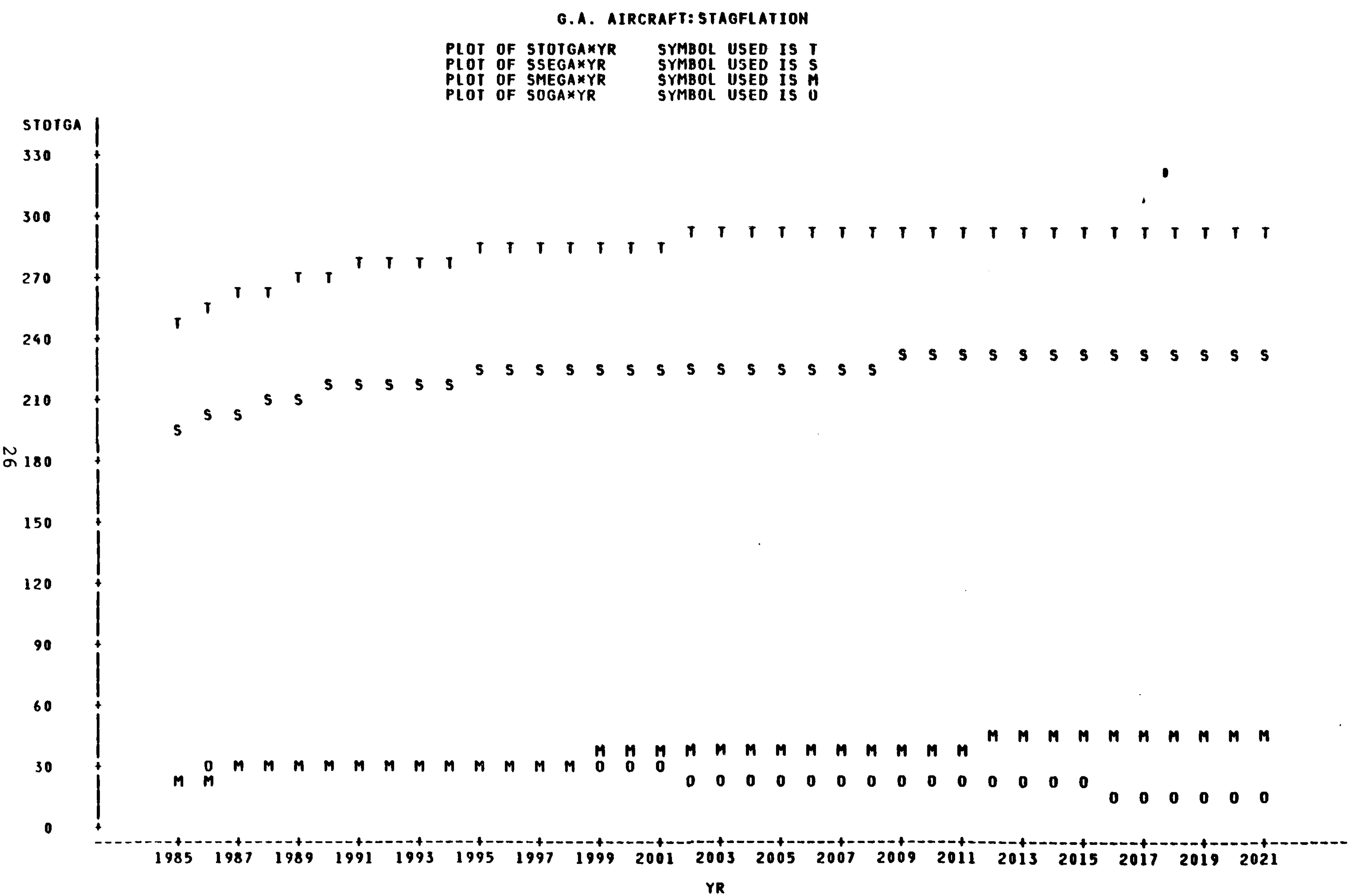
The sluggish economic conditions portrayed by the variables depicted above, portend grave conseqences for the aviation and communications industries. The slow increases in GNP imply low business activity in the stagflation economy. Low business activity, in turn, suggest a decrease in general aviation transportation demanded by private industry. The minimal increases in GNP also imply that capital will not be available to advance technology in the aviation or communications industries. Due to society's negative attitude towards technological development, economic growth increases at a very low annual rate. The reduced levels of employment coupled with minimal increases in Disposable Personal Income suggest a low demand for air transportation by the general public.

Aviation Industry

The demand for general aviation transportation decreases as a result of low business production. Evidence of this phenomenon is shown in the projected number of aircraft active in the general aviation fleet. The total number of aircraft active in the general aviation fleet increases at an average annual rate of 0.44% throughout the forecast period. Between 1985 and 2020, the total number of active aircraft in the general aviation fleet increases only 18% from 248,542 to 292,195 aircraft. The demand for multiengine aircraft by business entities accounts for most of the growth of active aircraft in the general aviation fleet.

Throughout the forecast period, the number of multiengine aircraft active in the general aviation fleet increases at an average annual rate of 1.7%. Between 1985 and the year 2020, the number of multiengine aircraft increases 86% from 254,538 to 472,770 aircraft. The number of single-engine aircraft active in the general aviation fleet increases at an average annual rate of 0.4%. By the year 2020, the number of single-engine aircraft active in the general aviation fleet increases 16% from 197,622 aircraft to 229,459 aircraft. The decrease in the utilization of single-engine aircraft is attributed to the effects of low Civilian Employment levels and low Disposable Personal Income levels. As the consumer's purchasing power decreases, so will the demand for recreational and instructional flying performed in single-engine aircraft. The general aviation fleet mix for the Stagflation Scenario is shown graphically in Figure 13. (The complete tabulation for the general aviation fleet is shown in Figure 2).

The decrease in demand for air transportation is reflected in FAA workload measures. Total aircraft operations at FAA towered airports increase at an average annual rate of 0.89% throughout the forecast period. By the year 2020, total aircraft operations at FAA towered airports increase 39% from 80 million aircraft operations in 1985 to 111 million operations.


G.A. AIRCRAFT: STAGFLATION
PLOT OF STOTGA*YR SYMBOL USED IS T
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1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021
YR

Figure 13

Itinerant aircraft operations at FAA towered airports increase at an average annual rate of 0.87% throughout the forecast period. Between 1985 and the year 2020, itinerant aircraft operations at FAA towered airports increase 40% from 53 million operations to 74 million operations. The general public's inability to afford aircarrier services because of the low level of Disposal Personal Income accounts for the low annual increase in itinerant aircraft operations. Another factor that relates to the low levels of itinerant aircraft operations at FAA towered airports is the low level of business production associated with a stagflation economy. Throughout the forecast period, local aircraft operations performed at FAA towered airports increase at an average rate of 0.93%. By the year 2020, local aircraft operations at FAA towered airports increase by 42% from 26 million operations in 1985 to 37 million. The low growth of local aircraft operations imply that fewer pilots will be trained during the forecast period. This phenomenon further suggests decreases in air traffic due to the decreases in the pilot population. The complete tabulations for FAA towered airport workload measures are shown in Figure 4. The measures displayed graphically in Figure 14 are the FAA towered airport workload measures for the Stagflation Scenario.

The growth rate in the number of aircraft handled by Air Route Traffic Control Centers increases at an average annual rate of 0.91%. By the year 2020, the number of aircraft handled by the Air Route

STAGFLATION:OPERATIONS

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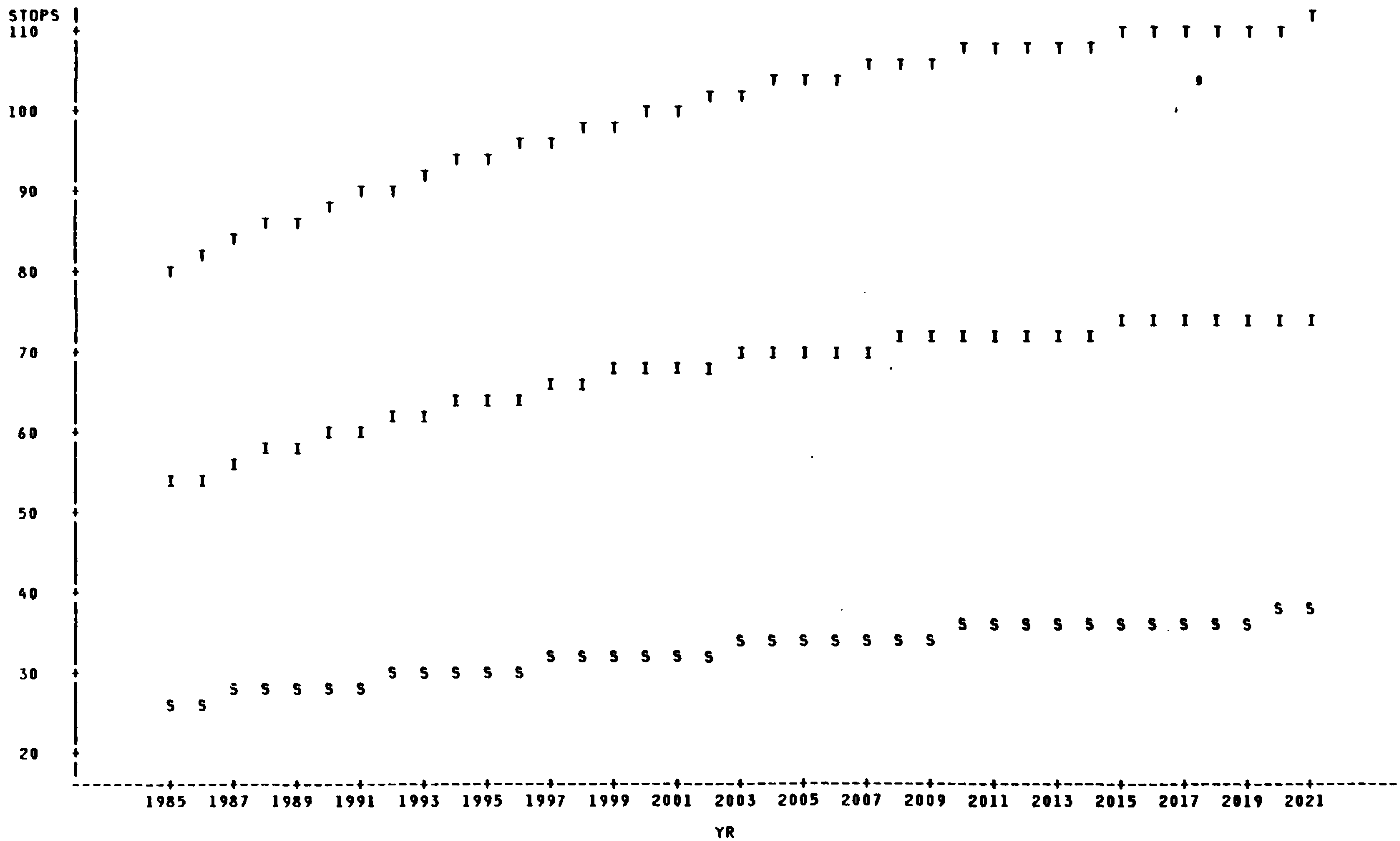

Figure 14

Traffic Control Centers increases 40% from 34.9 million aircraft in 1985 to 48.8 million aircraft. The increasingly low levels of increases in operations at Air Route Traffic Control Centers result from decreases in general aviation traffic and the pilot population level. The complete tabulations of enroute center work measures are given in Figure 6. The enroute measures for the Stagflation Scenario are displayed graphically in Figure 15.

ENROUTE WORKLOAD MEASURES: STAGFLATION

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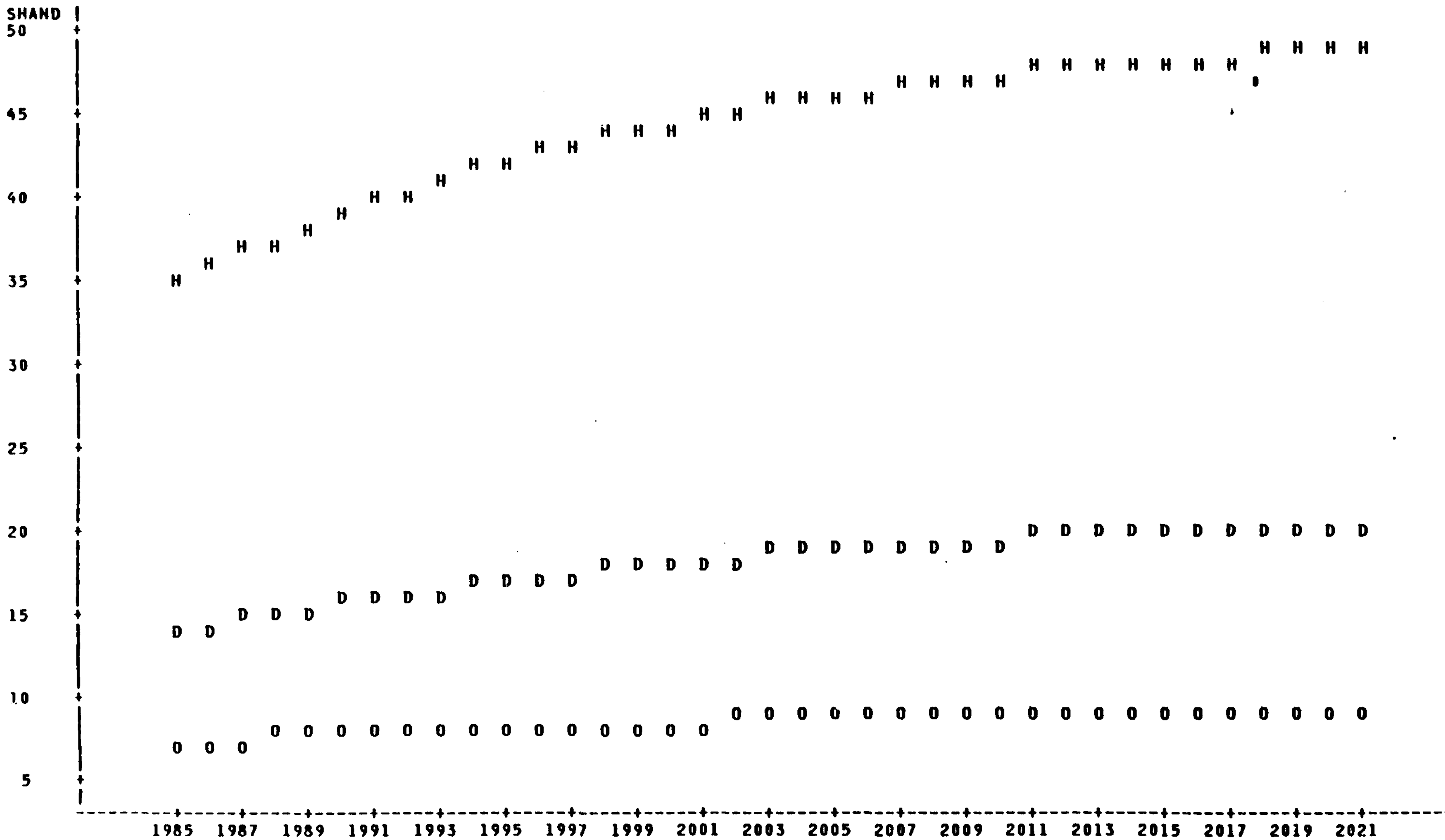


Figure 15

TECHNOLOGY FORECAST

This section presents the technology forecast for each socio-economic scenario. The forecasts are presented for selected components of the aviation communications system: microcomputers, input-output devices, switching systems, transmission systems, and communication satellites. The forecast for each component is presented in terms of key technological parameters.

Microcomputers

Data are provided concerning the likely future value of key technological parameters for two very large scale integrated (VLSI) systems: 1) a typical airborne VLSI instrumentation system and 2) a typical VLSI ground-based data processing system. The data include estimates of factors including power (watts), volume (cubic inches), cost (constant dollars), and/or speed (MIPS). The estimates for the unconstrained forecasts of the airborne and ground based data processing systems are shown in Figures 16 and 17, respectively. The unconstrained forecasts are based upon interviews with microcomputer industry experts.

The typical VLSI instrumentation system envisioned includes a display memory and controller, a 64 K-bit program memory (ROM), a 4 K-bit data memory (RAM), and a 4 K-bit bulk memory. The unconstrained forecast indicates that by 2,000 A.D. power equivalents will be reduced 42% over 1980 levels. In addition, volume requirements will be decreased by 69%. Further, unit costs will decrease by 59%.

AIRBORNE VLSI

INSTRUMENTATION SYSTEM CHARACTERISTICS

YEAR	CHARACTERISTICS		
	POWER (W)	VOLUME (IN^3)	COST ($1975)
1980	95	7,910	1,444
1985	77	805	901
1990	60	675	746
2000	55	590	585

Figure 16

GROUND-BASED VLSI

DATA PROCESSING SYSTEM CHARACTERISTICS

YEAR	CHARACTERISTICS		
	POWER (W)	SPEED (MIPS)	COST ($1975)
1980	520	3.13	28,365
1985	395	7.81	7,283
1990	270	15.63	3,097
2000	145	41.67	974

Figure 17

As noted in the Phase II report the unconstrained technology forecast has been deemed consistent with the balanced growth scenario. The technique described in the report was used to develop estimates of the relevant VLSI instrumentation system technological parameters for the stagflation and rapid growth scenarios. The forecast results for the three socioeconomic scenarios are shown in tabular and graphic form in Figures 18 to 23.

Power consumption, shown in Figures 18 and 19, is estimated to decline for the balanced growth scenario from 95 watts in 1980 to 55 watts in 2000, i.e a reduction of 42%. Power consumption requirements will diminish also under the stagflation scenario. However, the reduction in power requirements will be less than the 42% estimated for the balanced growth scenario. It is estimated that under the stagflation scenario power requirements will be 56.6 watts, in 2003, a reduction of 40% over 1980 levels. Power requirements under the rapid growth scenario will diminish more rapidly than under balanced growth. It is estimated that during 1996 under the rapid growth scenario power requirements will be 53.3 watts, or 44% less than 1980 levels.

The volume required for the VLSI instrumentation system will diminish under all three socioeconomic scenarios, but at different rates. Under the balanced growth scenario space requirements will decrease from 1910 cubic inches to 590 cubic inches in 2000. The 590 cubic inches represents a 69% reduction. The same reduction,

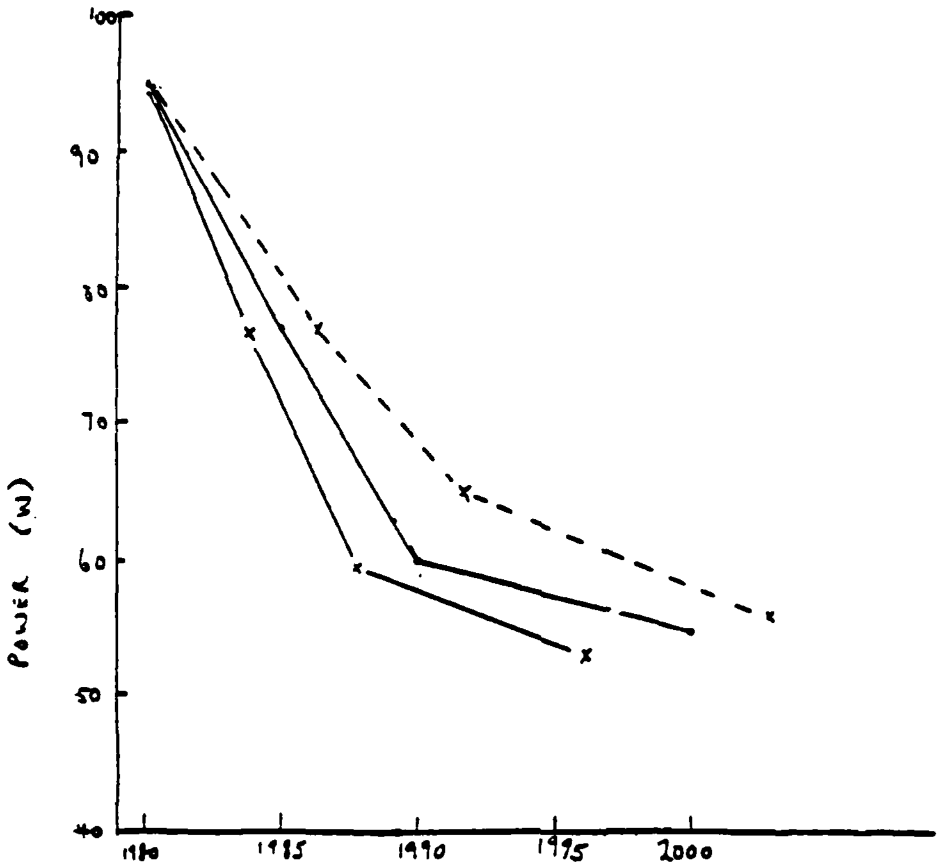
AIRBORNE VLSI
INSTRUMENTATION SYSTEM

POWER CONSUMPTION IN WATTS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	POWER (W)	YEAR	POWER	YEAR	POWER
1980	95	1980	95	1980	95
1985	77	1985.9	77.3	1983.9	76.7
1990	60	1991.8	60.6	1987.8	59.5
2000	55	2003	56.6	1996.1	53.3

Figure 18

AIRBORNE
VLSI INSTRUMENTATION SYSTEM
POWER REQUIREMENT FORECAST



KEY

o_______o Balanced Growth

x------x Stagflation

x_______x Rapid Growth

Figure 19

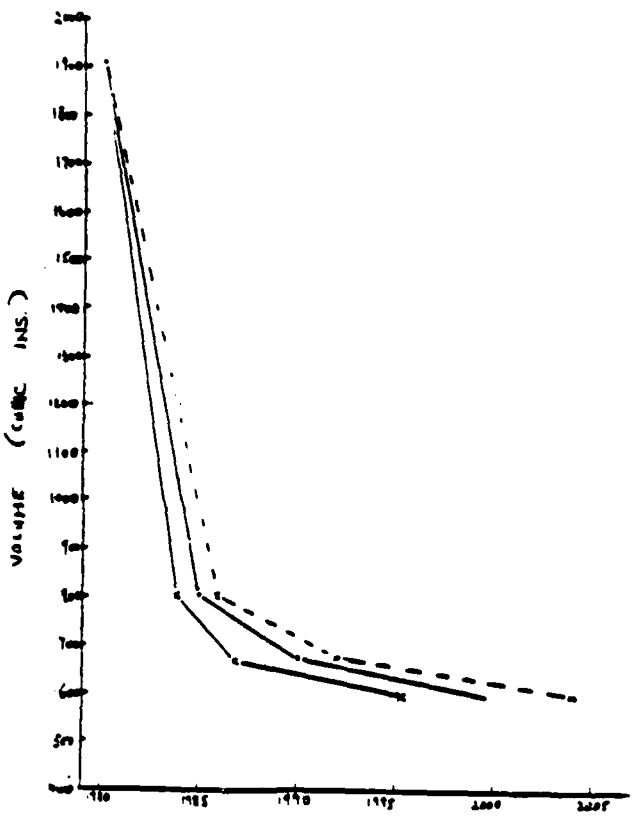
AIRBORNE VLSI
INSTRUMENTATION SYSTEM

VOLUME REQUIRED IN CUBIC INCHES

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	VOLUME	YEAR	VOLUME	YEAR	VOLUME
1980	1910	1980	1910	1980	1910
1985	805	1986	805	1984	805
1990	675	1992	675	1987	675
2000	590	2004	590	1995.4	590

Figure 20

AIRBORNE
VLSI INSTRUMENTATION SYSTEM
VOLUME FORECAST



KEY

o———o Balanced Growth

x-------x Stagflation

x———x Rapid Growth

Figure 21

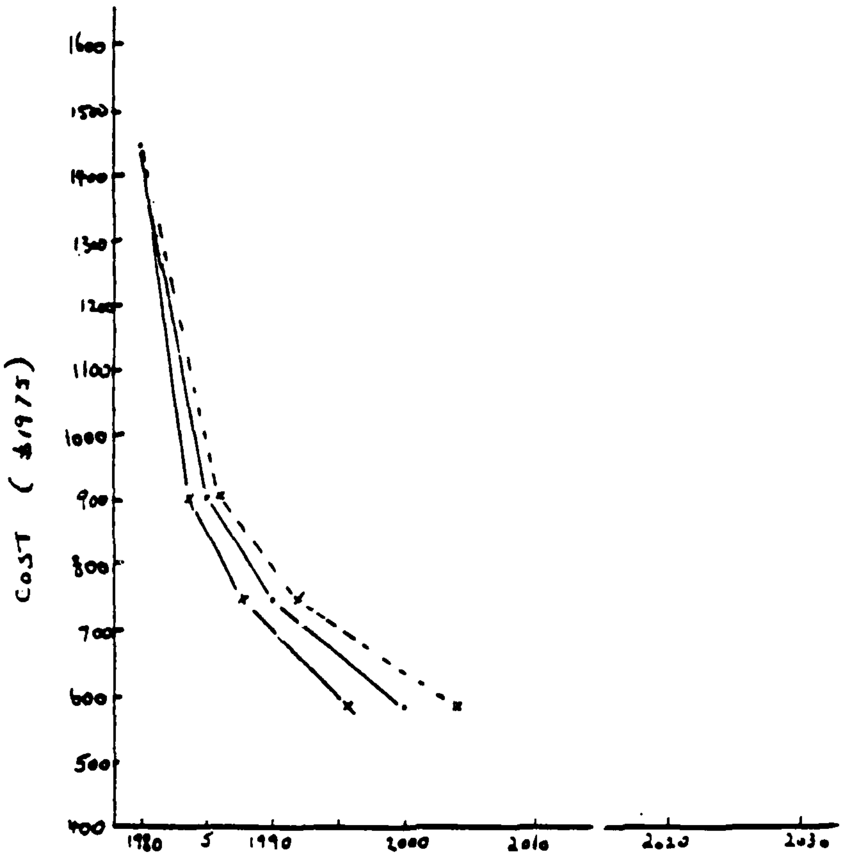
AIRBORNE VLSI
INSTRUMENTATION SYSTEM

COST IN 1975 DOLLARS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	COST	YEAR	COST	YEAR	COST
1980	1444	1980	1444	1980	1444
1985	901	1986	901	1983.9	901
1990	746	1992	746	1987.7	746
2000	585	2004	585.1	1995.4	584.9

Figure 22

AIRBORNE
VLSI INSTRUMENTATION SYSTEM
UNIT COST FORECAST



KEY

o———o Balanced Growth

x------x Stagflation

x———x Rapid Growth

Figure 23

i.e. 69%, is anticipated under the rapid growth and stagflation scenarios. However, 590 cubic inch size will not be achieved until 2004 under the stagflation scenario but by 1995 under the rapid growth scenario.

VLSI system cost will decrease in each of the three scenarios. The balanced growth scenario will result in system costs decreasing from $1,444 in 1980 to 585 in 2,000. The preceding represents a reduction of 59%. The absolute reduction in system cost in 2000 under the balanced growth scenario will not be attained until 2004 if the stagflation construct is in force. The system cost under the stagflation scenario during 2000 is estimated at 639, a 56% reduction from 1980 costs. It is expected that the balanced growth scenario systems costs for the year 2000, $585, will be attained four to five years sooner under the rapid growth scenario.

VLSI Ground-Based Data Processing System

The forecast data included in this section are based upon a typical VLSI data processing system equivalent to an Amdahl 470 or IBM 370 unit. The prototype VLSI data processing system will have 200,000 gates in the CPU and 32 M - bits of read-write high speed memory. The unconstrained technology forecast includes estimates of power (watts), speed (MIPS) and cost. The forecast estimates for the VLSI data processing system characteristics are presented in tabular form in Figures 24, 26, 28, and graphical form in Figures 25, 27, and 29.

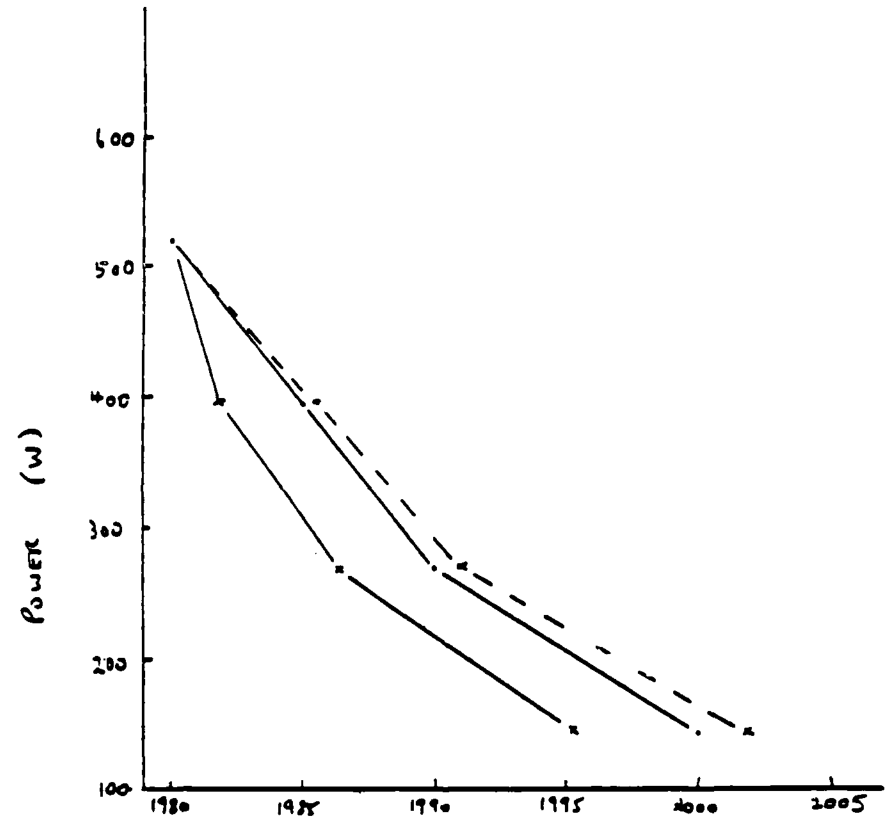
GROUND-BASED VLSI
DATA PROCESSING SYSTEM

POWER CONSUMPTION IN WATTS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	POWER	YEAR	POWER	YEAR	POWER
1980	520	1980	520	1980	520
1985	395	1986	394.9	1983.8	395
1990	270	1992	270.1	1987.7	270.9
2000	145	2004	145.2	1995.4	144.8

Figure 24

GROUND-BASED
VLSI DATA PROCESSING SYSTEM CHARACTERISTICS
POWER REQUIREMENTS FORECAST



KEY

o———o Balanced Growth

x------x Stagflation

x———x Rapid Growth

Figure 25

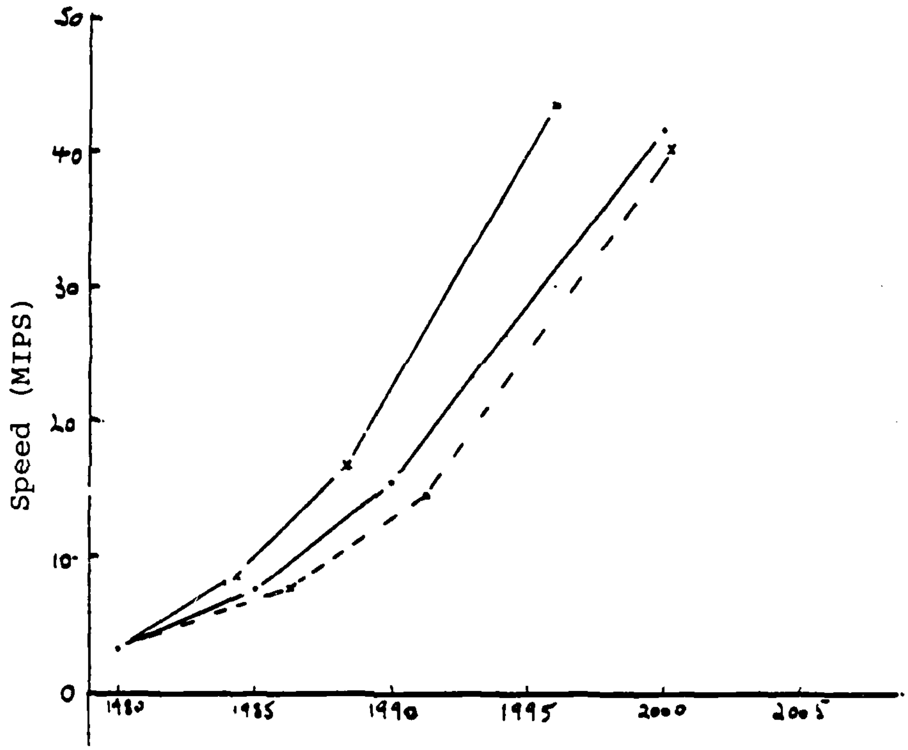
GROUND-BASED VLSI
DATA PROCESSING SYSTEM

SPEED in MIPS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	SPEED	YEAR	SPEED	YEAR	SPEED
1980	3.1	1980	3.1	1980	3.1
1985	7.8	1985.4	7.3	1984.3	8.4
1990	15.6	1991.1	14.7	1988.4	16.8
2000	41.7	2002.9	40	1996.1	43.5

Figure 26

GROUND-BASED
VLSI DATA PROCESSING SYSTEM
SPEED FORECAST



KEY

o——————o Balanced Growth

x------x Stagflation

x——————x Rapid Growth

Figure 27

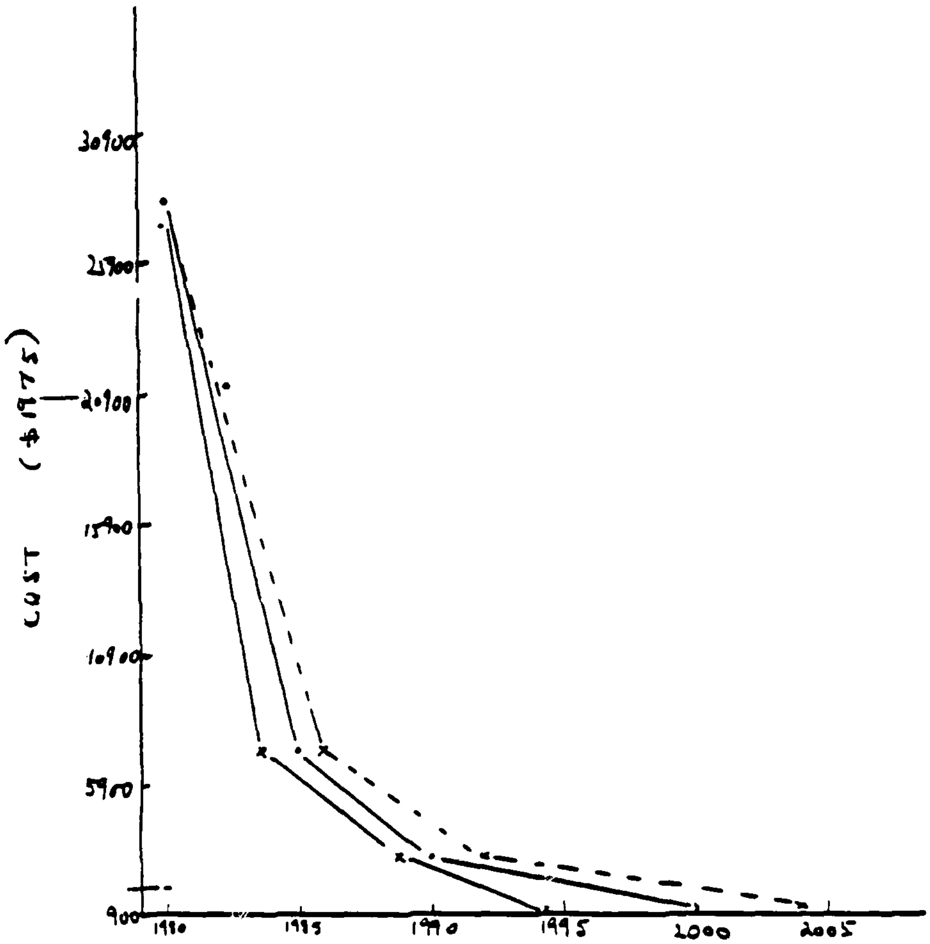
GROUND-BASED VLSI
DATA PROCESSING

COST IN 1975 DOLLARS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	COST	YEAR	COST	YEAR	COST
1980	28,365	1980	28,365	1980	28,365
1985	7,283	1986	7,283	1983.7	7,283
1990	3,097	1992	3,097	1988.8	3,097
2000	974	2004	974	1994.3	974

Figure 28

GROUND-BASED
VLSI DATA PROCESSING SYSTEM
COST FORECAST



KEY

o______o Balanced Growth

x------x Stagflation

x______x Rapid Growth

Figure 29

The power requirements for the VLSI data processing system will follow the trends delineated for the VLSI instrumentation technology; i.e., they will be diminished over the forecast period. In the approximate 20 year period, a 72% reduction will be realized, declining from 520 watts in 1980 to 145 watts in 2000. Power requirements under the stagflation scenario will not achieve the same level of reduction as the balanced growth scenario until 2004. It is estimated that the power requirements for the VLSI data processing system under stagflation during 2000 will be 187 watts, equivalent to a 64% reduction over the 1980 level. The 145 watt power requirement level for the rapid growth scenario will be attained four to five years earlier than projected for the balanced growth scenario.

The ability to process data or the speed of the VLSI data processing system is likely to increase rapidly under all three scenarios. The unconstrained or balanced growth forecast is estimated to increase from 3.1 to 41.7 MIPS between 1980 and 2000, a change of 1245%. Increased data processing speed will occur also in the stagflation scenario. However, the speed attained during 2000 under stagflation will be 34.2 MIPS, an increase of 1003%. The greatest increase in system speed will occur under the rapid growth scenario. It is anticipated that during 1996 system speed will attain 43.5 MIPS under the rapid growth scenario.

The cost of the VLSI data processing system will decrease rapidly. A decrease of 97%, from $28,365 in 1980 to $974 during 1994 is forecast for the rapid growth scenario. Under the balanced growth scenario the 97% decline in VLSI data processing cost will occur by 2000, while the same percentage will not be realized until 2004 for the stagflation growth scenario.

Input-Output Devices

The typical prototype input-output device considered in the technology forecast is comprised of a microcomputer control complex with a 100 M-bit RAM, a 75 M-byte tape bulk storage module, a hardcopy output device, a TV-quality video input system, a 25 inch video display screen, and standard audio and keyboard I/O devices.

It is expected that the technology of input-output devices will undergo great change independent of the socioeconomic scenarios. The scenarios, however, will impact the rate of such change. The impact of the scenarios are estimated in terms of size (cubic inches) and cost.

The estimates of the forecasted technology parameters for each scenario are displayed in tabular form in Figures 30 and 32 and in graphic form in Figures 31 and 33.

The input-output devices are expected to decrease 65% from the 1980 size of 39,700 cubic inches to 13,740 cubic inches. Under the rapid growth scenario this decrease is forecast to occur during

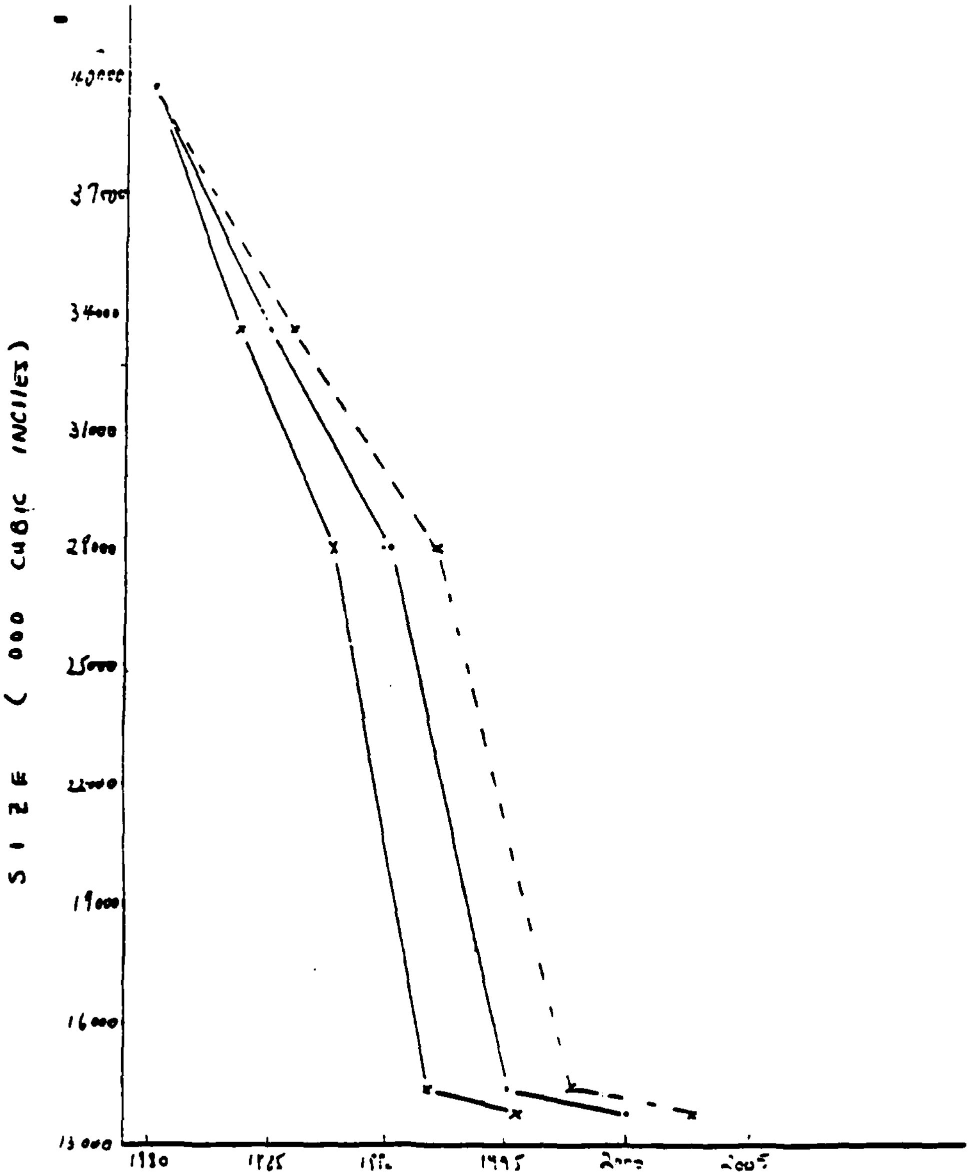
INPUT-OUTPUT TERMINAL CHARACTERISTICS

SIZE IN CUBIC INCHES

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	SIZE	YEAR	SIZE	YEAR	SIZE
1980	39,700	1980	39,700	1980	39,700
1985	33,550	1986	33,550	1983.9	33,550
1990	28,000	1992	28,000	1987.7	28,000
1995	14,450	1997.6	14,450	1991.6	14,450
2000	13,740	2002.7	13,740	1995.4	13,740

Figure 30

INPUT-OUTPUT TERMINAL SIZE FORECAST



KEY

o———o Balanced Growth

x- - - - - - -x Stagflation

x———x Rapid Growth

Figure 31

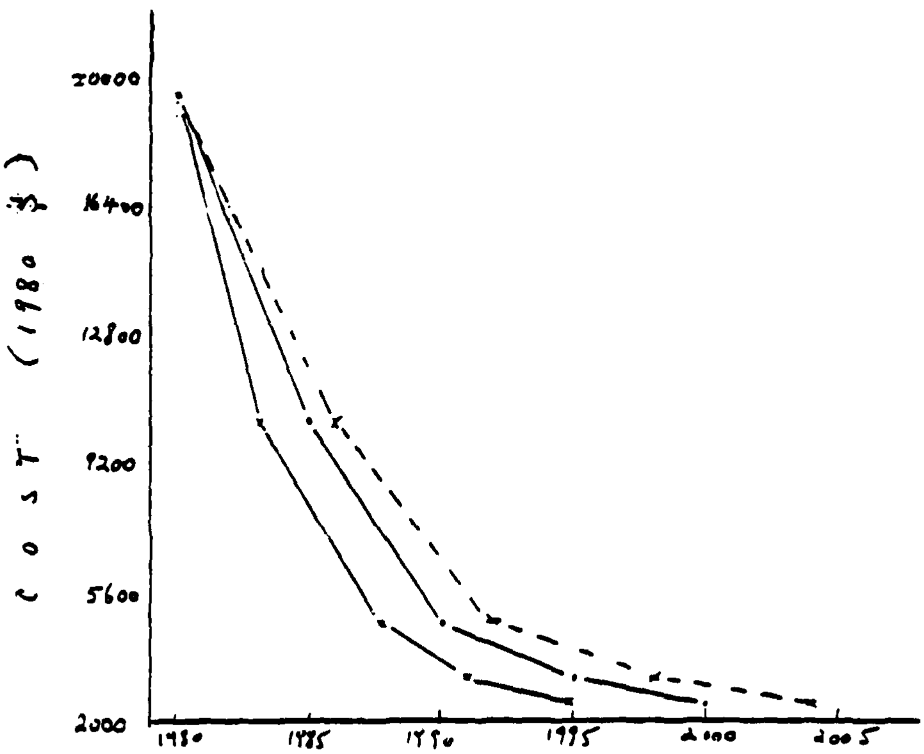
INPUT-OUTPUT TERMINAL CHARACTERISTICS

COST IN 1980 DOLLARS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	COST	YEAR	COST	YEAR	COST
1980	19,626	1980	19,626	1980	19,626
1985	10,314	1986	10,314	1983.3	10,314
1990	4,835	1992	4,835	1987.7	4,835
1995	3,146	1998	3,146	1991.5	3,146
2000	2,491	2004	2,491	1995	2,491

Figure 32

INPUT-OUTPUT TERMINAL COST FORECAST



KEY

o———o Balanced Growth

x------x Stagflation

x———x Rapid Growth

Figure 33

1995, some four to five years earlier than that of the balanced growth scenario which is expected to decline to the same size by 2000. Under the stagflation scenario the input-output device are not expected to attain 13,740 cubic inches until the latter half of 2002.

The cost of input-output devices is expected to follow the patterns established for unit size. That is, an 87% reduction is expected to occur, declining from $19,626 in 1980 to $2,491 by 1995, 2000 and 2004 for the rapid growth, balanced growth and stagflation scenarios, respectively.

<u>Switching Systems</u>

The nature and unconstrained forecast of switching systems is contained in the Phase II report. The switching system forecast was qualitative rather than quantitative. That is, estimates of the mix of switching systems were provided rather than numeric projections of technology parameters. As such, it is necessary to cast this section in a manner different from the previous sections. The principle difference will be in the nature of the parameter rather than the technique of forecast.

The data obtained is the unconstrained (i.e., balanced growth) forecast as shown in Figure 36. The data provided are a forecast of the proportions of different switching systems in service for specific years. It was assumed that the parameter of impact is the proportion of electronic switching systems in service. The

proportion of electronic switching systems in service was forecasted for the rapid growth and stagflation scenarios with the technique delineated.

The forecasted proportion of electronic switching systems for all scenarios is shown in Figures 34 and 35. The balanced growth scenarios indicate that by 1995 all switching will be electronic. However, it is estimated that under the stagflation scenario complete electronic switching will not occur until after 1997. It is anticipated that under the rapid growth scenario electronic switching will be in full force during the latter months of 1991.

The relative mix of switching systems for each scenario are shown in Figures 36, 37, and 38. The relative mixes are based on subjective allocation, based on the forecast of electronic switching in Figure 34.

Transmission System

The most important transmission systems are based upon fiber optic and satellite technology. The unconstrained forecast of fiber optic technology is based primarily upon technical considerations and limitations. The unconstrained forecast for satellite technology derives from mathematical extrapolation with respect to the features of current technology.

Fiber optics remains a fledgling technology. As such, parameters for characterizing the technology are yet to be developed.

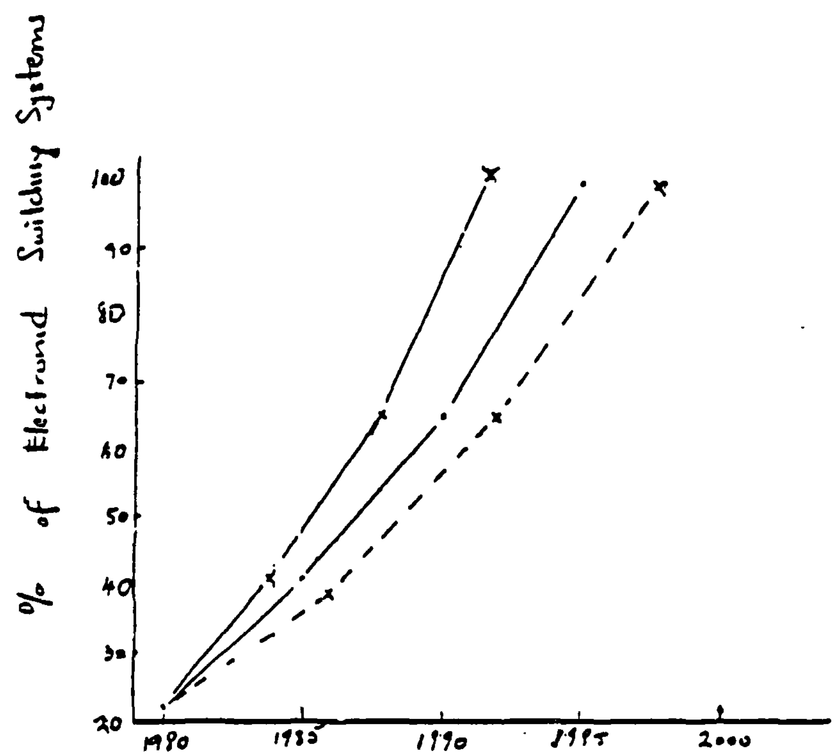
SWITCHING SYSTEMS FORECAST

ELECTRIC SWITCHING AS PERCENT OF TOTAL SWITCHING

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	PERCENT	YEAR	PERCENT	YEAR	PERCENT
1980	22	1980	22	1980	22
1985	41	1985.9	38.7	1983.9	41.3
1990	65	1991.9	64.5	1987.8	65.5
1995	100	1997.9	99.4	1991.7	100

Figure 34

SWITCHING SYSTEMS FORECAST
PERCENTAGE ELECTRONIC



KEY

o_______o Balanced Growth

x------x Stagflation

x_______x Rapid Growth

Figure 35

SWITCHING SYSTEMS BY TYPE
AS PERCENT OF TOTAL SYSTEMS
BALANCED GROWTH SCENARIO

Year	Electronic	#5 Cross Bar	#1 Cross Bar	Panel	Step By Step
1980	22	43	7	2	26
1985	41	33	5	0	21
1990	65	20	3	0	12
1995	100	0	0	0	0

Figure 36

ACUMENICS

MIX OF SWITCHING SYSTEMS

STAGFLATION

Year	Electronic	#5 Cross Bar	#1 Cross Bar	Panel	Step By Step
1980	22	43	7	2	26
1989.6	39	35	5	0	21
1999.7	62	33	3	0	12
2010.0	95	5	0	0	0

Figure 37

MIX OF SWITCHING SYSTEMS

RAPID GROWTH

Year	Electronic	#5 Cross Bar	#1 Cross Bar	Panel	Step By Step
1980	22	43	7	2	26
1983.3	41	33	5	0	21
1986.6	66	19	3	0	12
1989.9	100	0	0	0	0

Figure 38

For the purpose of this forecast, estimates have been provided for the cost of fiber optic communication units. The forecasted cost values for fiber optic levels are shown in tabular form and graphic form, Figures 39 and 40, respectively. The unconstrained forecast values are shown in the balanced growth section of Figure 39. If the balanced growth scenario obtains, then fiber optic link costs are expected to decline from $11,000 in 1980 to $570 in 2000, 95% by early 1993. An equivalent comparison between the balanced growth and rapid growth extrapolation indicates that a 95% decline in cost will be achieved during 1998 under the rapid growth scenario, almost two years earlier than forecast for the balanced growth scenario. As expected the 95% decline will be achieved the latest if the stagflation scenario should hold. The price of $570 will not be attained until sometime during the latter half of 2003 for this scenario, 5-6 years later than forecast for the rapid growth scenario, and 3-4 years after that of the balanced growth scenario.

The unconstrained forecast for satellite technology projects values for weight in orbit and number of wide band channels per unit (Figures 41 and 42). Under the unconstrained or balanced growth scenario the weight in orbit is expected to increase from 14,500 KG in 1980 to 67,583 KG in 2000, or 366%. The 366% gain in orbit weight is anticipated during 1995 under the rapid growth scenario; but not until 2004 under the stagflation scenario.

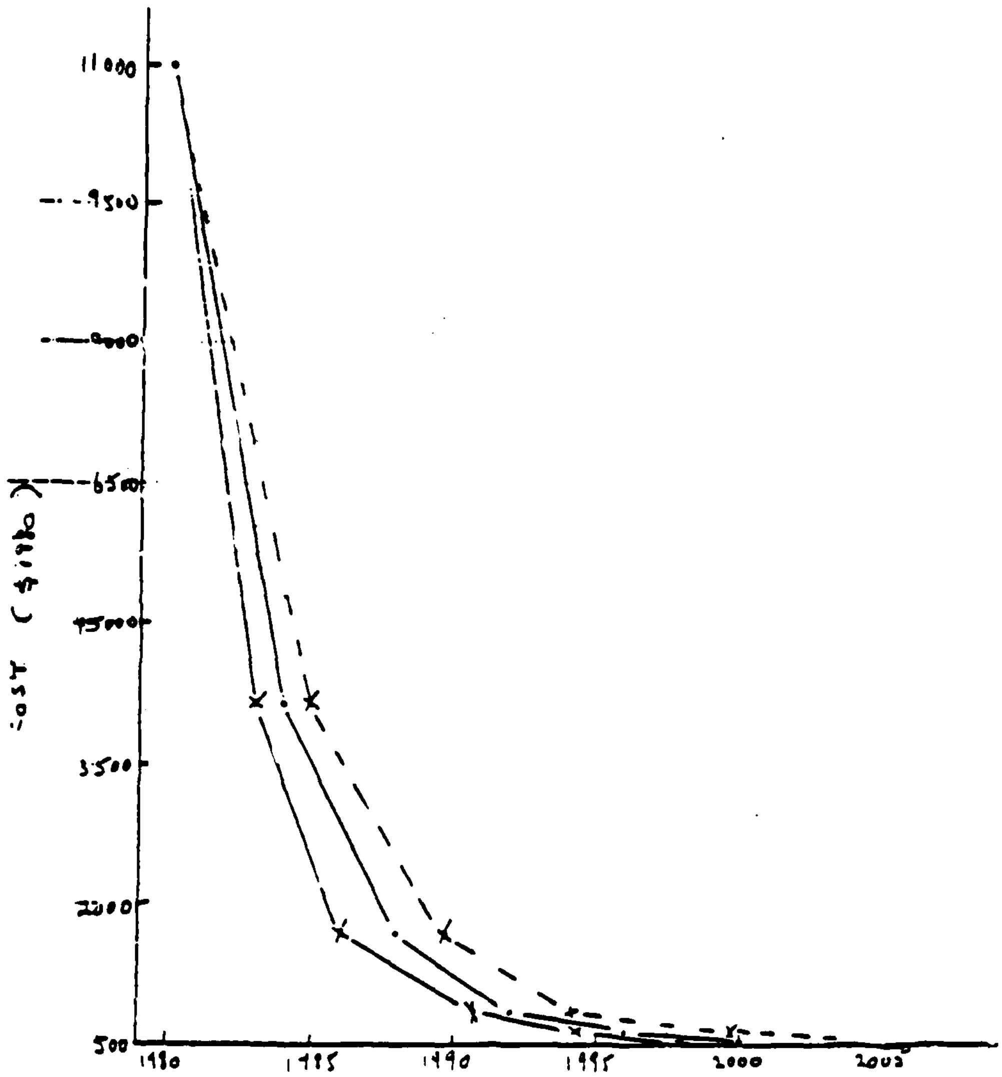
FIBER OPTIC LINK

COST IN 1980 DOLLARS

BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	COST	YEAR	COST	YEAR	COST
1980	11,000	1980	11,000	1980	11,000
1984	4,150	1984.8	4,150	1983.6	4,150
1988	1,700	1989.7	1,700	1986.5	1,700
1992	880	1994.1	880	1990.6	880
1996	650	1999.9	650	1994.5	650
2000	570	2003.7	570	1998.2	570

Figure 39

FIBER OPTIC LINK
COST FORECAST



KEY

o———o Balanced Growth

x------x Stagflation

x———x Rapid Growth

Figure 40

ACUMENICS

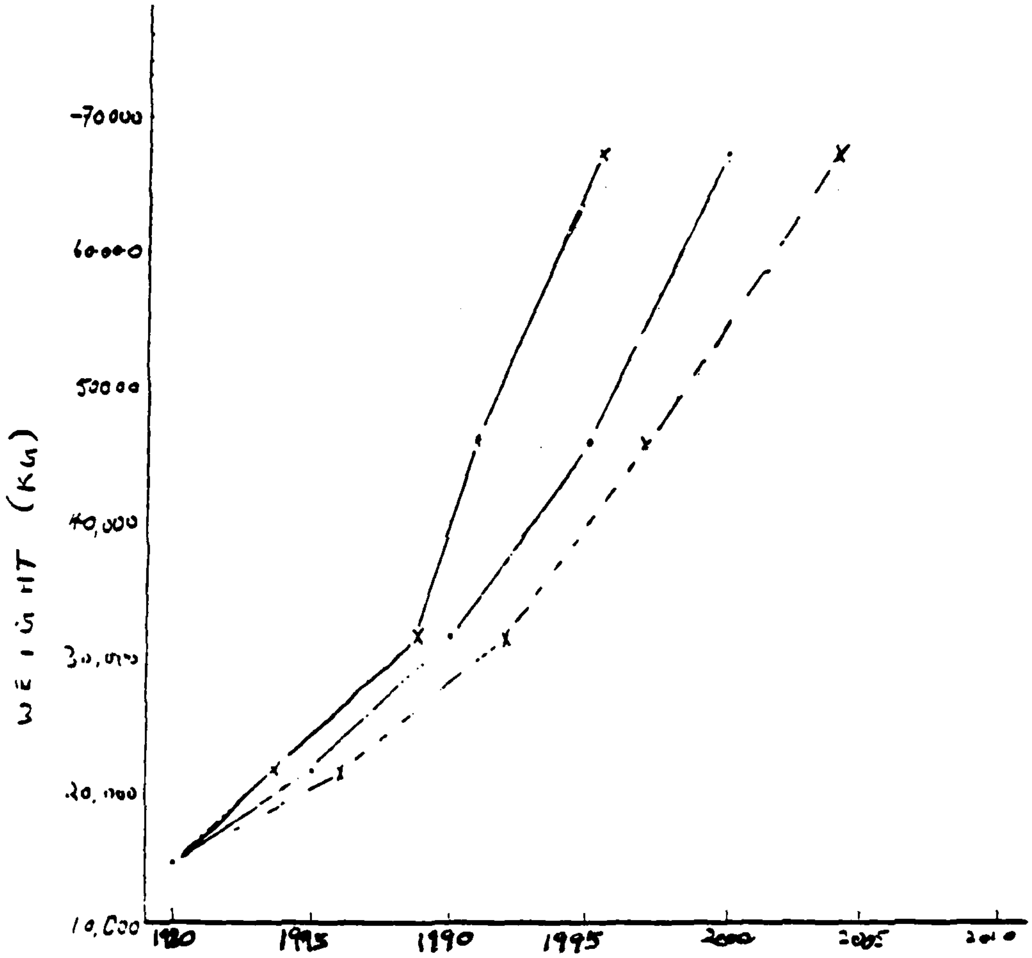
COMMUNICATION SATELLITE CHARACTERISTICS

WEIGHT IN KILOGRAMS

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	WEIGHT	YEAR	WEIGHT	YEAR	WEIGHT
1980	14,500	1980	14,500	1980	14,500
1985	21,305	1986	21,305	1983.6	21,305
1990	31,304	1992	31,304	1988.8	31,304
1995	45,996	1997	45,996	1991	45,996
2000	67,583	2004	67,583	1995.4	67,583

Figure 41

COMMUNICATION SATELLITE
WEIGHT FORECAST



KEY

o———o Balanced Growth

x------x Stagflation

x———x Rapid Growth

Figure 42

ACUMENICS

The number of wide band channels under the balanced growth scenario is expected to increase from 612 in 1980 to 3822 in 2000. (Figures 43 and 44). It is anticipated that 2725 channels will be available per satellite by 1995 under balanced growth, by 1998 under stagflation, and by early 1991 under rapid growth. The estimated leasing cost per channel for the three scenarios is given in Figures 45 and 46.

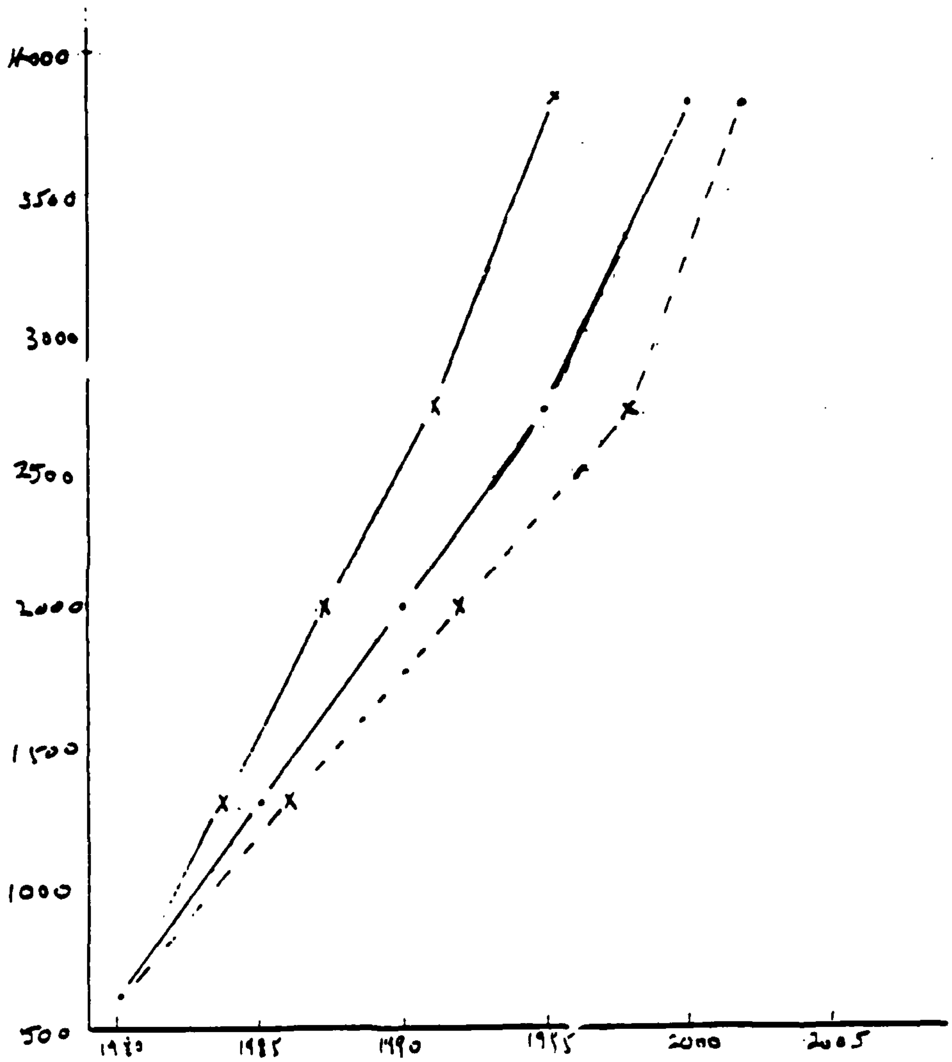
NUMBER OF WIDE BAND

CHANNELS PER SATELLITE

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	CHANNEL	YEAR	CHANNEL	YEAR	CHANNEL
1980	612	1980	612	1980	612
1985	1310	1984.7	1081	1983.6	1391
1990	2005	1989.4	1548	1987.3	2166
1995	2725	1994.3	2037	1990.9	2965
2000	3822	2002.7	2881	1994.2	4117

Figure 43

FORECAST OF
NUMBER OF WIDE BAND CHANNELS PER SATELLITE



KEY

o______o Balanced Growth

x------x Stagflation

x______x Rapid Growth

Figure 44

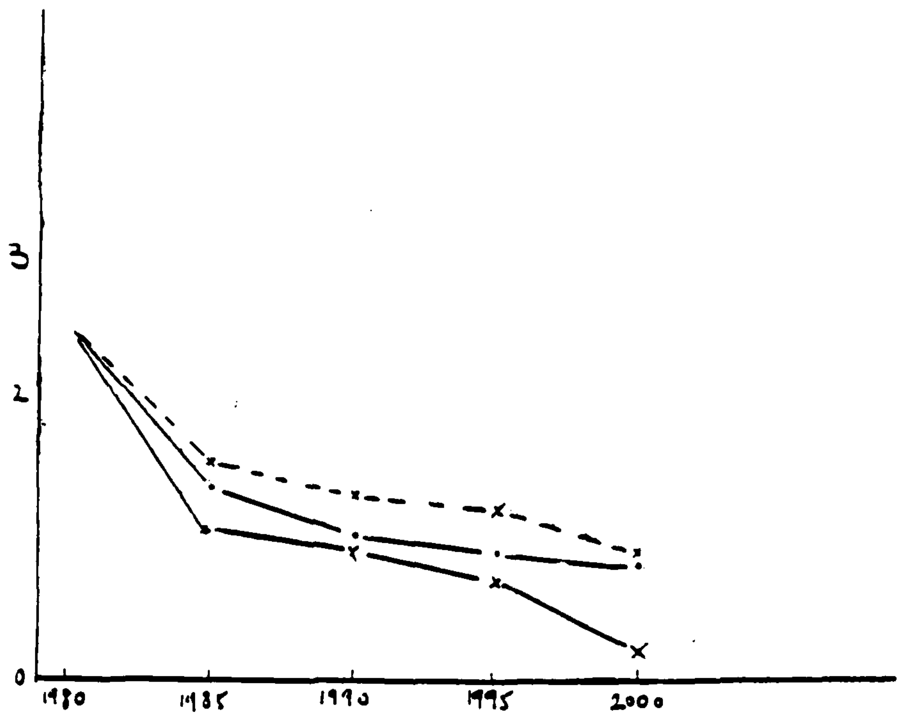
SATELLITE CHARACTERISTICS

LEASING COST/CHANNEL ($M/YEAR)

SCENARIO					
BALANCED GROWTH		STAGFLATION		RAPID GROWTH	
YEAR	COST	YEAR	COST	YEAR	COST
1980	2.5	1980	2.5	1980	2.5
1985	1.35	1985	1.54	1984.9	1.03
1990	1.02	1990	1.3	1990	.9
1995	.9	1995	1.2	1995	.7
2000	.8	2000	.9	2000	.2

Figure 45

FORECAST OF
SATELLITE LEASING
COST PER CHANNEL



KEY

o________o Balanced Growth

x-------x Stagflation

x________x Rapid Growth

Figure 46

Future ATC Concepts

The major subsystems that determine the aviation communication requirements are shown in Figure 47. The commercial communication systems available in the year 2020 will be a mix of satellites, optical fibers, various microwave and other terrestrial systems. A dedicated ground-to-ground communications system for civil aviation is unlikely to be cost-effective. Consequently, the ground-to-ground voice and data communication system is assumed to be essentially commercial in all three scenarios.

In Figure 48 three system alternatives are selected to match the future socioeconomic and technology forecasts. The only assumption implicit in Figure 48 is how the various ATC systems are likely to be partitioned between space and terrestrial systems.

In the rapid growth scenario, technology will provide for all functions of the CONUS ATC system to be space-based, except for ground-to-ground communications, which will be a mix of space and terrestrial systems.

In the balanced growth scenario, several of the functions continue to be terrestrially-based but are aided by satellites to extend coverage and capacity. The satellite-aided concepts would allow for lower reliability spacecraft requirements, less in-orbit space capability, et cetera. In addition, the fully satellite-based system requires multiple-beam satellites to make efficient use of

Major Subsystems Determining Aviation Communications

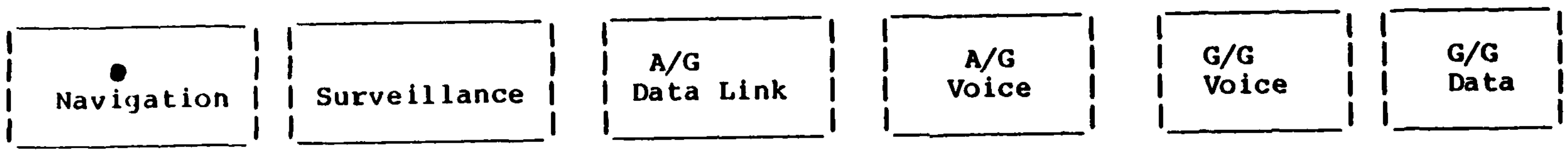


Figure 47

System Alternatives Matched with Future ATC Scenarios

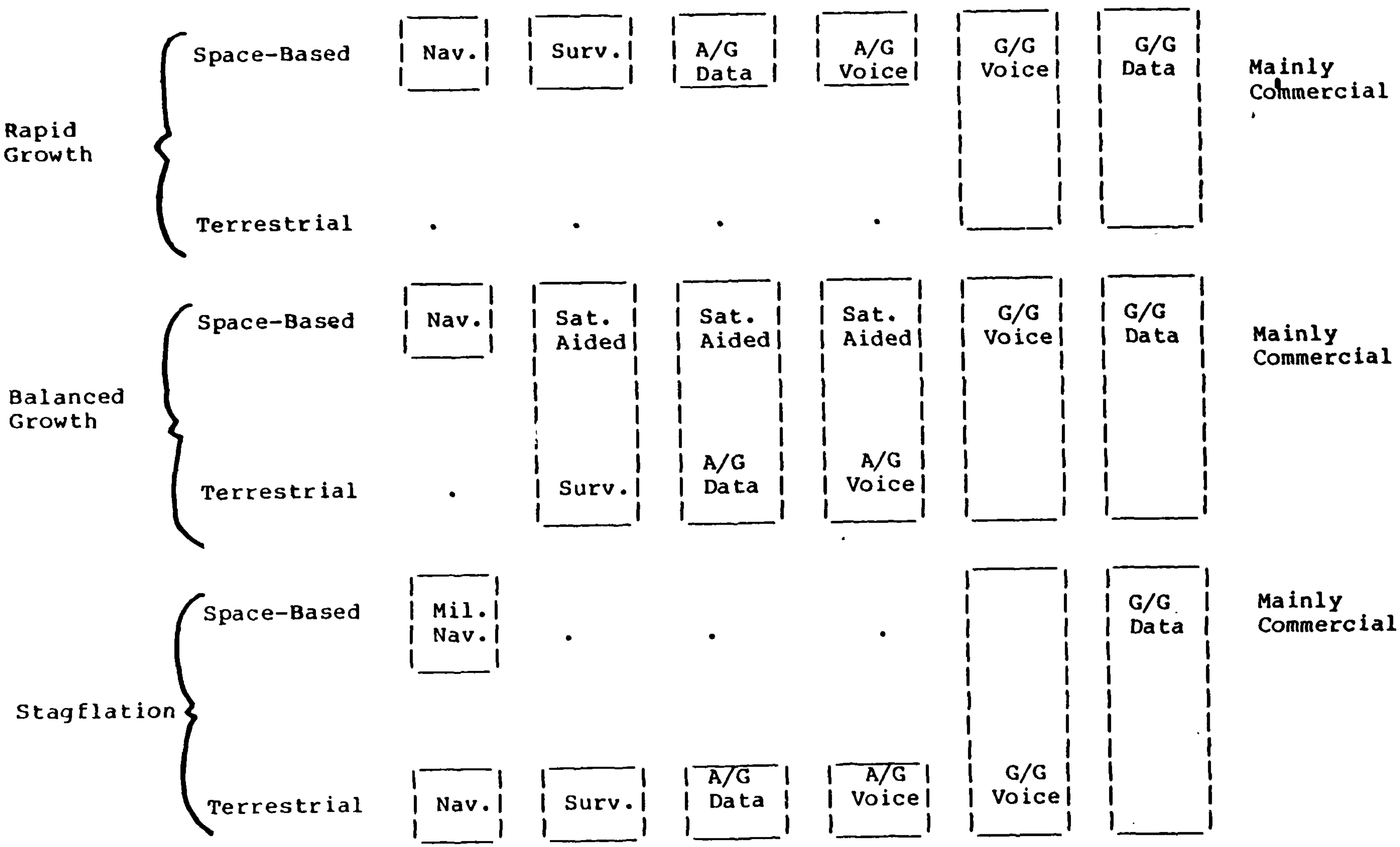


Figure 48

spectrum. The satellite aided concept requires fewer beams, hence it is less technologically advanced. Satellite-aided systems would also be evolutionary; however, they would require different rules for frequency assignment between terrestrial and satellite. Finally, in the stagflation scenario, the terrestrial system, as projected in FAA plans for the late 1990's, is assumed to change little in configuration. The military navigation system will probably evolve into GPS, but the VOR/DME will continue as the chief civil aid. However, due to the communication industry's current levels of capability, a large fraction of the ground-to-ground communications will be space based, even in this scenario. Potential aviation communication requirements can now be treated further in terms of the three conceptual configurations.

Space-Based Navigation, Surveillance and Communication System: Rapid Growth Scenario

The likelihood of a space-based system in the rapid growth scenario is due to the low operations and maintenance costs of such systems due to significantly reduced terrestrial facilities and reduced manpower. In addition, the space-based system will be able to offer higher coverage and improved performance necessary for the huge traffic increase. A relevant example for comparision of the cost-effectiveness of space-based systems is NASA's TDRSS (Tracking and Data Relay Satellite System), which is to replace the majority of current ground-based NASA tracking stations next year with two operational geosynchronous satellites and two in-orbit spares. This system will cost about one-half the current cost of $200 million per year, and will provide a significant increase in coverage.

a. System Description

In Figure 49, the space-based configuration is shown to differentiate the main space, ground, and user segments. The system is composed of a constellation of low-orbit and geosynchronous satellites. A centrally located Satellite Control Center (SCC) collects and processes the surveillance data and disseminates this data to the various ATC facilities, mainly via commercial communications satellites. Terrestrial links fill in the short distance connections and various commercial telephone networks.

Considerable consolidation would become feasible in most of the terrestrial facilities.

The number of enroute Air Route Traffic Control Centers (ARTCC) could be reduced to, at most, 4 or 5. The Flight Service Stations could be significantly reduced by integrating their services into the ARTCC and TCCs. The meterological data could be broadcast, ideally, via the communication satellite to the aircraft, airlines, and other ATC users. Interfaces with DOD, Canada, etc., would also connect mainly through the satellite communication system.

Consolidation of the terrestrial facilities would produce lighter voice and data requirements per facility, making the cost-effectiveness of the communication satellite network even more effective. The communications satellite could monitor various unattended and automated facilities by means of data collection platforms. The platform data would be communicated to the appropriate terrestrial center--e.g., centralized maintenance facility.

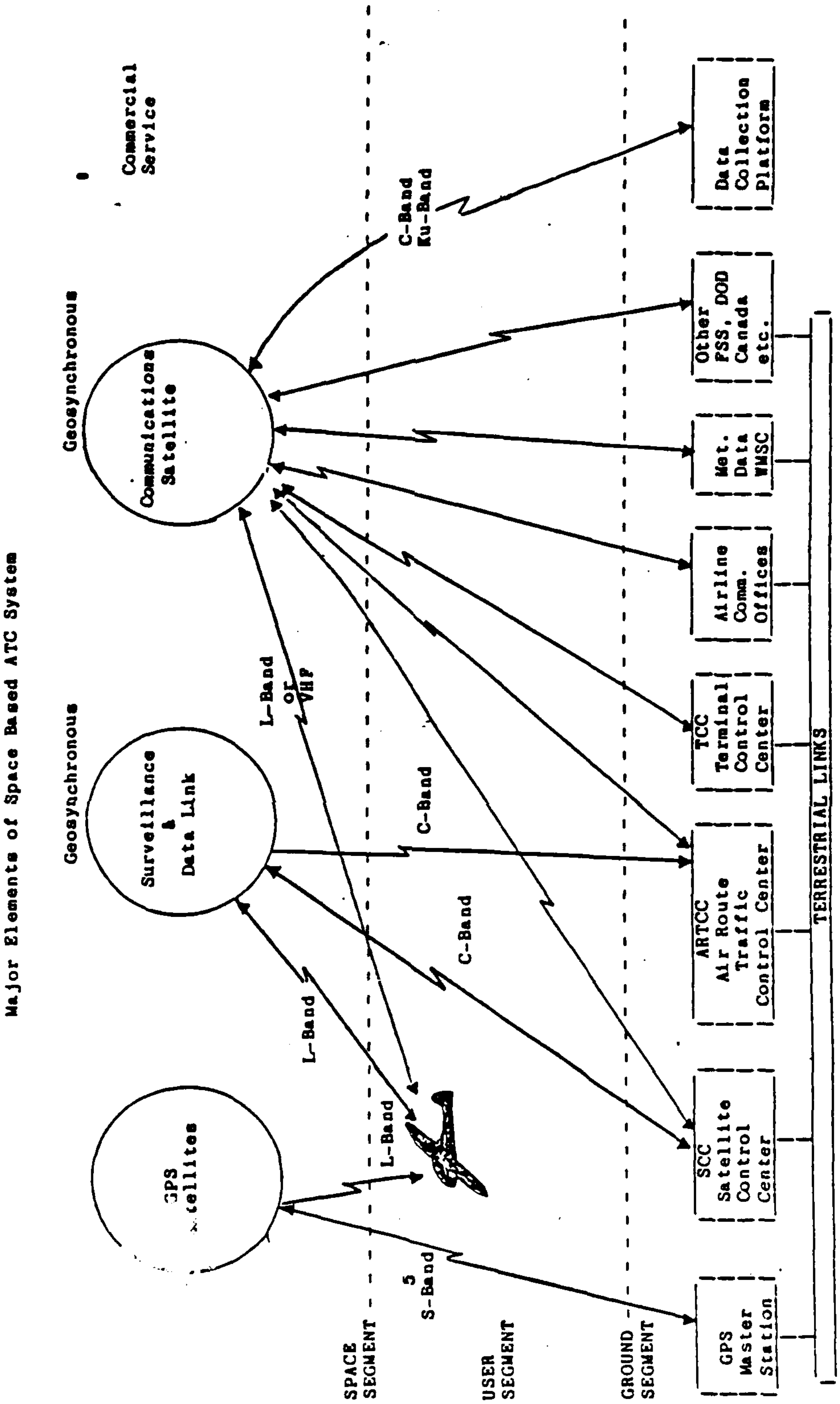

Major Elements of Space Based ATC System
Geosynchronous
Geosynchronous
Commercial Service
GPS Satellites
Surveillance & Data Link
Communications Satellite
SPACE SEGMENT
USER SEGMENT
GROUND SEGMENT
5 S-Band
L-Band
L-Band
L-Band or VHF
C-Band
C-Band
C-Band Ku-Band
GPS Master Station
SCC Satellite Control Center
ARTCC Air Route Traffic Control Center
TCC Terminal Control Center
Airline Comm. Offices
Met. Data WMSC
Other FSS, DOD Canada etc.
Data Collection Platform
TERRESTRIAL LINKS

Figure 49

The basic navigation and surveillance system is GPS based. For surveillance, position data computed on the aircraft from the relative times-of-arrival (TOA) of ranging signals from 4 satellites are reported via the geosynchronous satellite data link. In the surveillance process, sufficient time is allocated for both aircraft acquisition and tracking. The acquisition mode involves determining the identity and initial location of new aircraft entering the system. Once an adequate degree of information is obtained, the aircraft is placed into the tracking mode. In this mode, aircraft regularly provide position data to the ground via one of two direct access procedures: polling or time-division-multiple access (TDMA).

With polling, aircraft are discretely interrogated, once each surveillance update cycle, and respond accordingly. An interrogation contains the aircraft address, appropriate ATC messages and it could possibly be requested for other information. Analysis of the capacity of polling versus TDMA shows polling to be superior.

With TDMA, the aircraft, after acquisition, is assigned a time slot in which to respond during each update cycle. Sufficiently accurate knowledge of system time is required on-board the aircraft, which comes from GPS. Either TDMA or polling associated with surveillance is via a data link. This data link can be employed for non-navigation or non-surveillance air-to-ground communications, but the system would have to change significantly to handle the higher capacity. Consequently, the communications satellite handles all the other data and voice communications.

Navigation and surveillance data are from the source 4 GPS satellites. Independence between the two functions is obtained by (a) employing separate GPS receivers and (b) verifying aircraft-derived range by comparing it with an independently derived range measurement based on the TOA of an aircraft surveillance reply.

Figure 50 illustrates the satellite constellation for the proposed concept. The GPS satellites are in 12-hour, 63° inclined orbits. The Surveillance Data Link satellites (SD) are in geosynchronous orbit. In the year 2020, a single satellite could be produced to serve the full capacity requirements of CONUS surveillance. A second satellite would be included as an in-orbit backup. A second operating satellite may be added to improve GPS accuracy in some areas.

The Surveillance (SD) Satellite communicates with aircraft on L-band and to the SCC on C-band. The SD Satellites could also be used to assist the aircraft navigation receiver in selection of the 4 GPS satellites to use, calibration corrections, and aiding acquisition of the GPS receiver. Many of these concepts are being studied for reduction of GPS user costs. To maintain the high level of system integrity, the system concept includes Calibration stations deployed around CONUS for providing correction data (e.g. propagation delays) to maintain both navigation and surveillance accuracy.

Space-Based Surveillance/Data

System Constellation for CONUS
(Voice and Communications Satellites are separate)

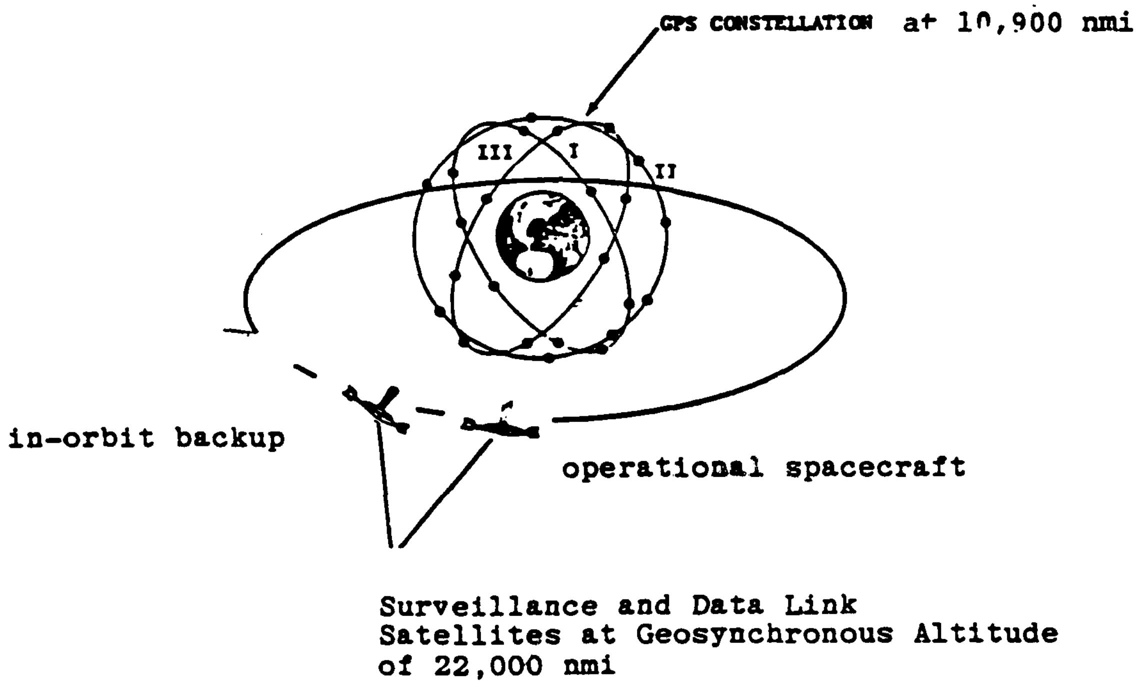


Figure 50

The majority of air-ground and ground-ground communications traffic is on the geosynchronous commercial satellites. The aircraft-to-satellite link will be at either L-band or VHF, while the satellite-to-ground link will be at either C-band or Ku-band, as assigned for commercial communications. As far as the system concept is concerned, the air-to-ground communications may be on one satellite and the ground-to-ground communications on another.

The space, user, and ground segments are further discussed below, in terms of the communications system. The related surveillance navigation system is further described in Appendix A of the Phase III report.

b. Communications Subsystem for the Space-Based Concept

In this section, the communications subsystem for the space-based concept is further developed. To do this, it is useful to identify the following major parts of the subsystem:

1. Air-ground communications in which there are large numbers of users:

   o aircraft 700,000

   o ground

     - terminals 2,000-5,000
     - airlines
     - airports
     - TCC

   Capacity of this part is principally set by air-to-ground voice frequency.

2. Ground-to-ground communications between the major facilities such as the SCC, ARTCC, National Flow Control Center, Centralized FSS's, National Weather Service, Central Airline Offices and TCC's should, at most, add up to 20-100. Capacity of this link is determined mainly by data requirements.

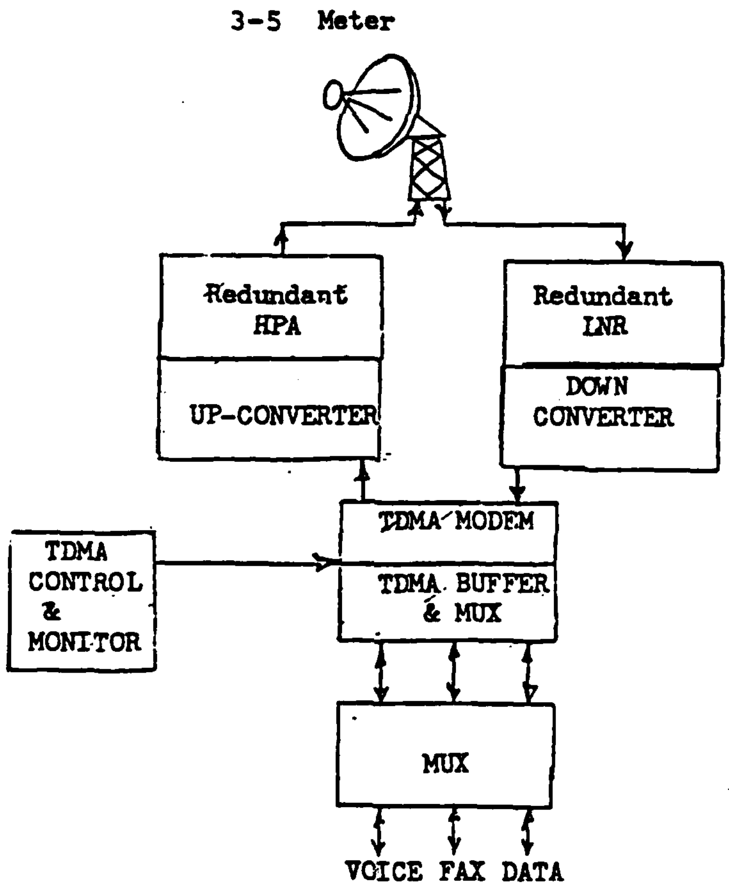
3. Ground-to-ground communications within major facilities--basically the large and medium hub airports. Capacity here is small for current services, but could grow significantly with new uses of communications.

4. Ground-to-ground communications from large numbers of data collection platforms to a few centralized facilities. This would be the basic configuration for the Remote Monitoring and Maintenance System (RMMS) for the various smaller terrestrial facilities.

Except for interfacility communications of category (3), all others above could be integrated into a single communications satellite. However, due to the special nature of the air-ground communications, which require low-cost user terminals, it is desirable to separate the space segment into two types of spacecraft. For the air-ground communications, a multi-beam satellite with high power and voice links is selected. For the ground-to-ground communications of category (2), a data communications domestic satellite service is assumed. This same service, in addition, could be used to sequentially collect data from all the DCP's and send it to a central facility.

In the year 2020, domestic satellite traffic will be served, at least, in the C-band and Ku-band and the 20/30 GH_3 band. Due to the propagation problems at the higher bands, the satellite service for category (2) should be mainly at C-band. Ku-band should be feasible in most areas except for regions with very heavy rainfalls. Technology forecasts indicate that the most effective access schemes will be TDMA. Typical terminals will have 3-5 meter antennas, and the satellites will employ satellite beam switching, making them cost-effective by keeping the major ATC facilities in as few beams as possible. A block diagram of a TDMA terminal is shown in Figure 51.

A Typical Terminal for Ground-to-Ground Communications via Satellite



TDMA - Time Division Multiple Access
LNR - Low Noise Receiver
HPA - High Power Amplifier
MUX - Multiplexer

Figure 51

There are many projections of the configurations of future domestic satellites for wideband tracking -- the best for category (2) service would be simply selected on the basis of commercial offering.

c. Air-Ground Communications Satellite Concept

In the case of a system concept for air-ground communications, further specificity is necessary. In Figure 52, the proposed multi-beam satellite for air-ground communications is shown. This satellite concept is based on a study by General Electric Company sponsored by NASA. The concept was developed in significant detail for application to future land-mobile communications; it is adapted here with few changes. However, the proposed system capacity and concepts of modulation, multiplexing, performance, etc., may be modified with little impact on the viability and capability of the basic issue of air-ground communications via satellite in the rapid growth scenario.

The terrestrial mobile telephone market is growing rapidly, and the impact of this mass market can be used in designing the air-ground communications to have similar narrow-bound FM channels. These channels are allocated 30 KH$_3$, each with IF bandwidth of 25KH$_3$ and a voice message bandwidth of 300H$_3$-3KH$_3$. Assuming a 10MH$_3$ bandwidth from aircraft to satellite, and a 10MH$_3$ from satellite to aircraft, permits a total of 333 duplex voice channels. A single beam satellite would not be sufficient to serve the 100,000 or more peak CONUS instantaneous airborne traffic forecast for the rapid growth scenario. A 69 beam satellite with the pattern shown in Figure 53 would be able to increase the frequency reuse by a factor of 23.

Spacecraft Design Applicable for Air/Ground Aviation Communications

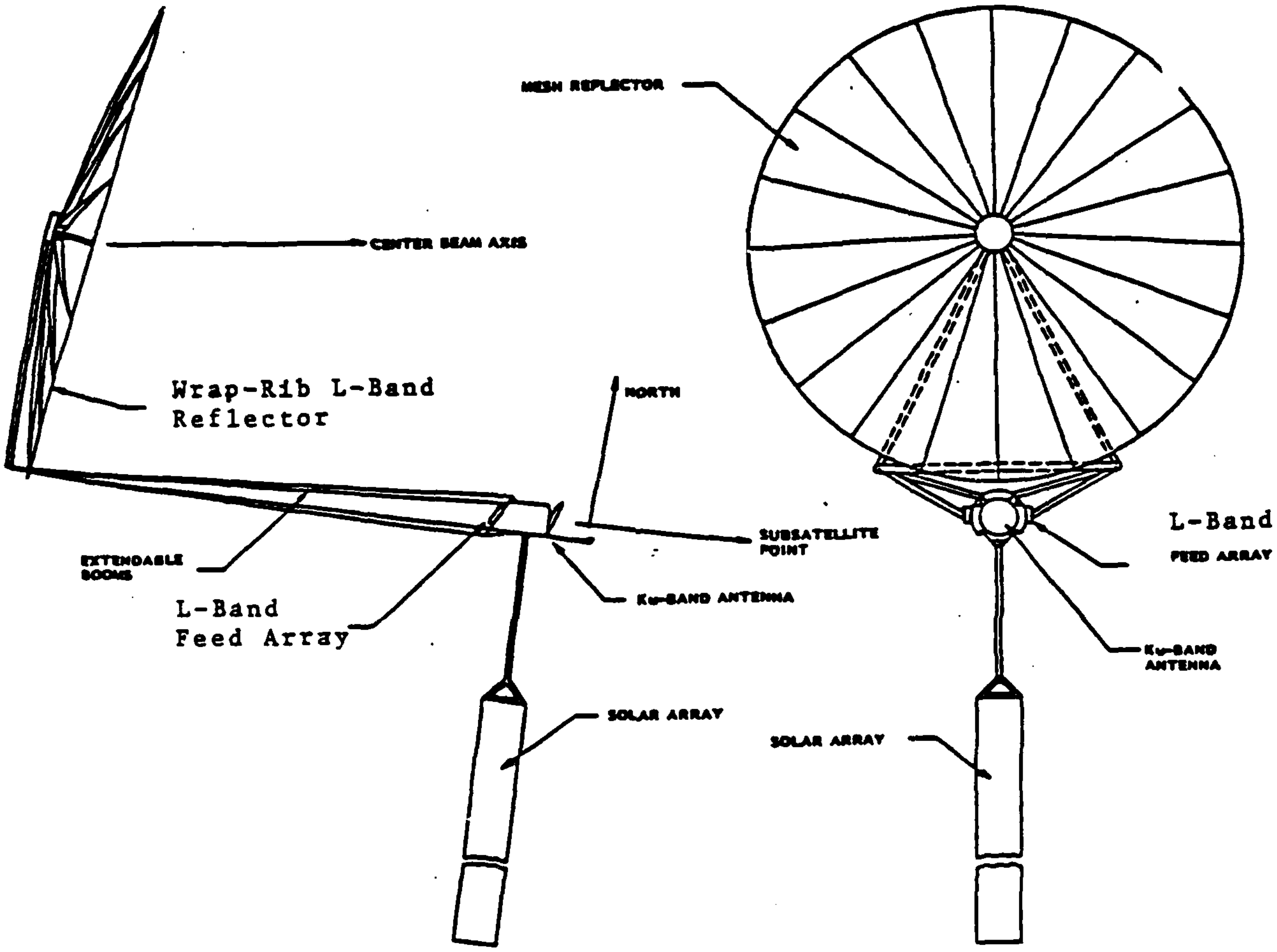
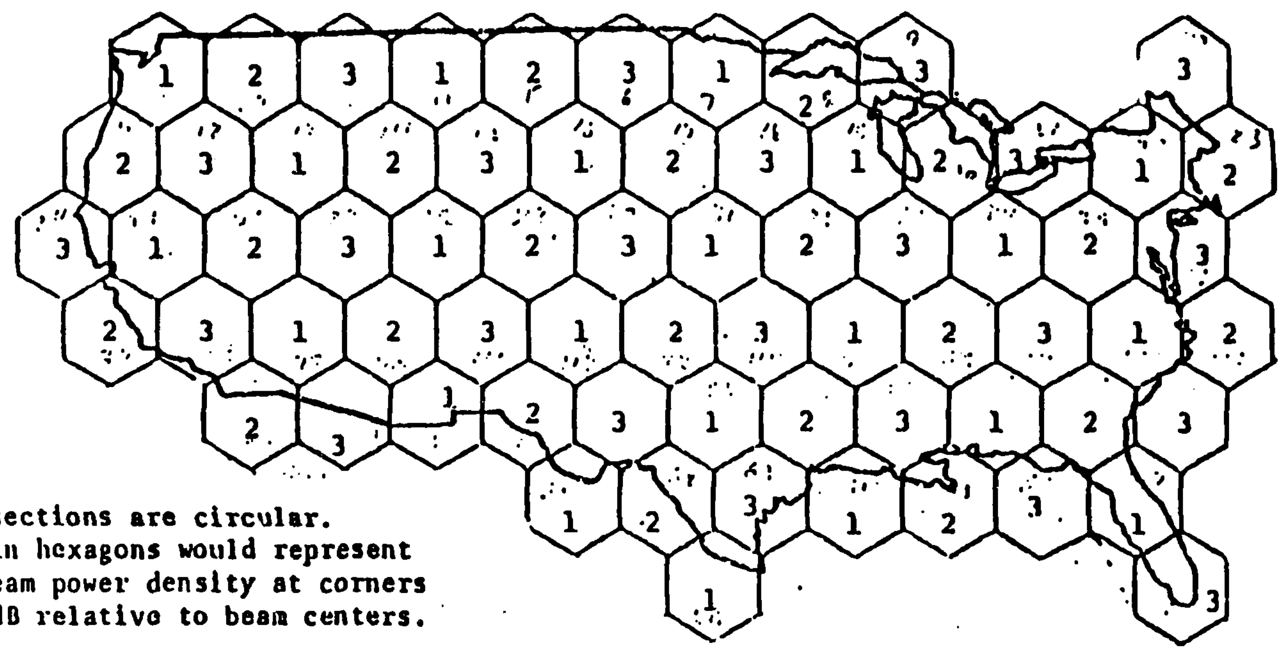


Figure 52

Satellite "Cells" Serving Contiguous States



Actual beam cross sections are circular. Circles inscribed in hexagons would represent 0.5° beamwidth. Beam power density at corners of hexagons is -4 dB relative to beam centers.

Numbers in hexagons refer to channel sets of frequency reuse pattern.

Figure 53

The 333 channels within the allocated frequency band are divided into 3 sets as follows:

Set 1: 1, 4, 7, 10, 13 ... 331

Set 2: 2, 5, 8, 11, 14 ... 332

Set 3: 3, 6, 9, 12, 15 ... 333

The numbers within the cells of Figure 53 represent the channel set in the beam. Note that no adjacent beams have the same set of channels in order to minimize co-channel interference. Each beam or footprint of the satellite has 111 channels, each of transmission and reception.

Every aircraft in the system is capable of operating on all channels in all sets of frequencies. Within each set of frequencies there is at least one "calling" (aircraft-to-satellite) and one "control" (satellite-to-aircraft) channel. When an aircraft's unit is activated, it automatically searches and locks onto a control channel. When the pilot dials a number, the request is transmitted over the calling channel. The calling channel signal goes to the satellite control station, which assigns a talking channel pair to the aircraft via the control channel, and connects the call to the called party through the public terrestrial network.

The transponder concept assumes a satellite switch which has 69 L-band inputs and 69 Ku-band outputs as shown in Figure 54. A 69x69 satellite switch is more advanced than today's communications satellites. Currently, the TDRSS/Advanced Westar is the only DOMSAT

Basic Satellite Switching Configuration

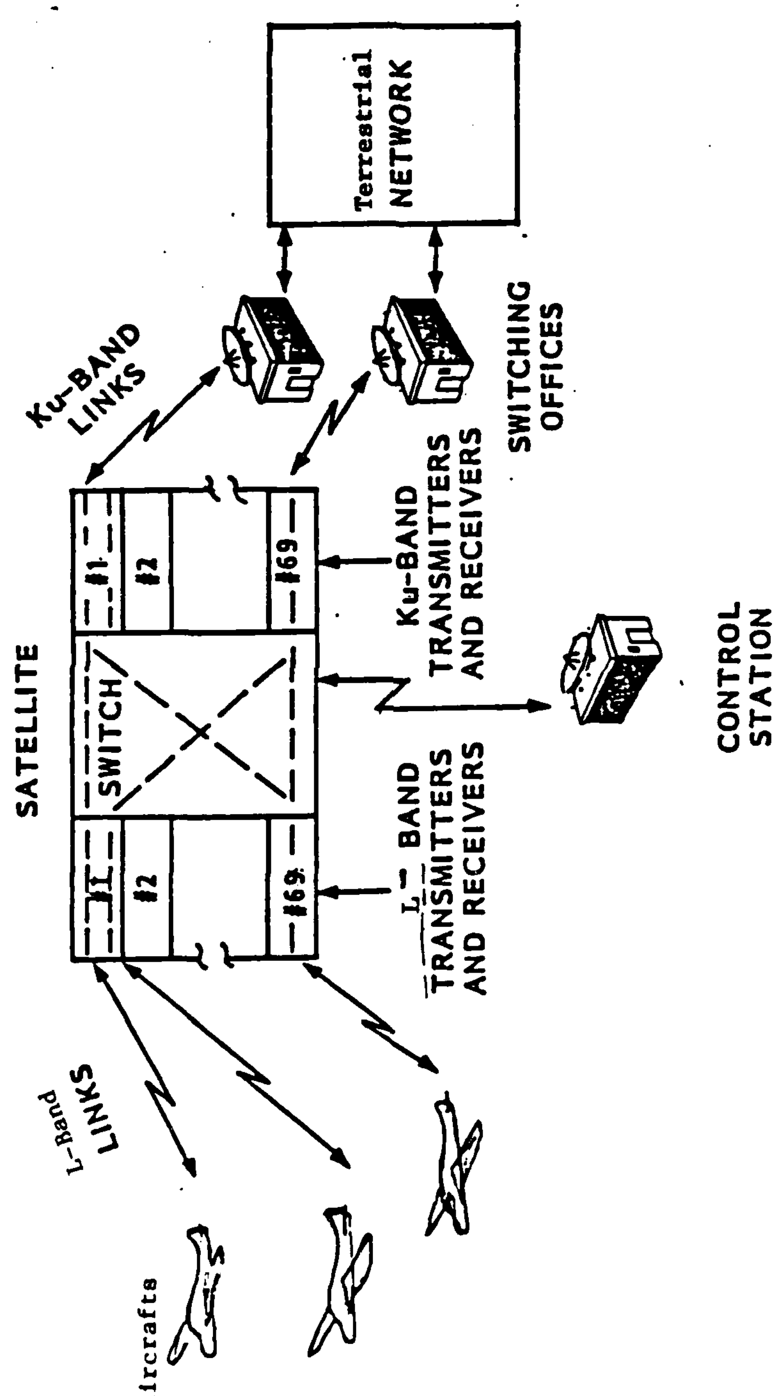


Figure 54

which will have a 4x4 beam switch. However, on-board switching, as indicated in Figure 54, will be available by the early 1990's, since it significantly reduces earth station switching requirements and it can eliminate double hops in aircraft-to-aircraft communications.

Figure 55 is a more detailed description of the satellite transponder. The figure shows each beam's FDM channels as being downconverted (D/C) to an IF demultiplexed and then switched to the addressed destination beam. The switch outputs are appropriately processed, multiplexed and up-converted (U/C) before retransmission. The processing required ahead of the switching can range from down-converting to a convenient IF and separating the channels with filters, to demodulation of each channel followed by analog-to-digital conversion, digital switching, digital-to-analog conversion, remodulation and multiplexing for transmission. Such an advance switch eliminates the switching required at the earth stations and may be a significant cost savings in total operation and maintenance costs.

The General Electric study considers a non-switching transponder satellite design. It would be a lower order of technology, and it will have double hops in the aircraft-to-aircraft links. Other work has been reported by COMSAT for a TDMA concept instead of the FDMA approach presented here. However, that concept was developed for a lower capacity -- although it could also be extended.

System Capacity

Capacity is a function of the grade of service and the number of channels. The capacity of a single footprint with 108 channels,

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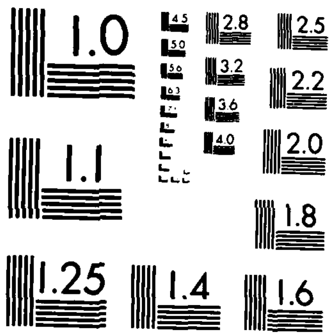

Block Diagram of Transponder

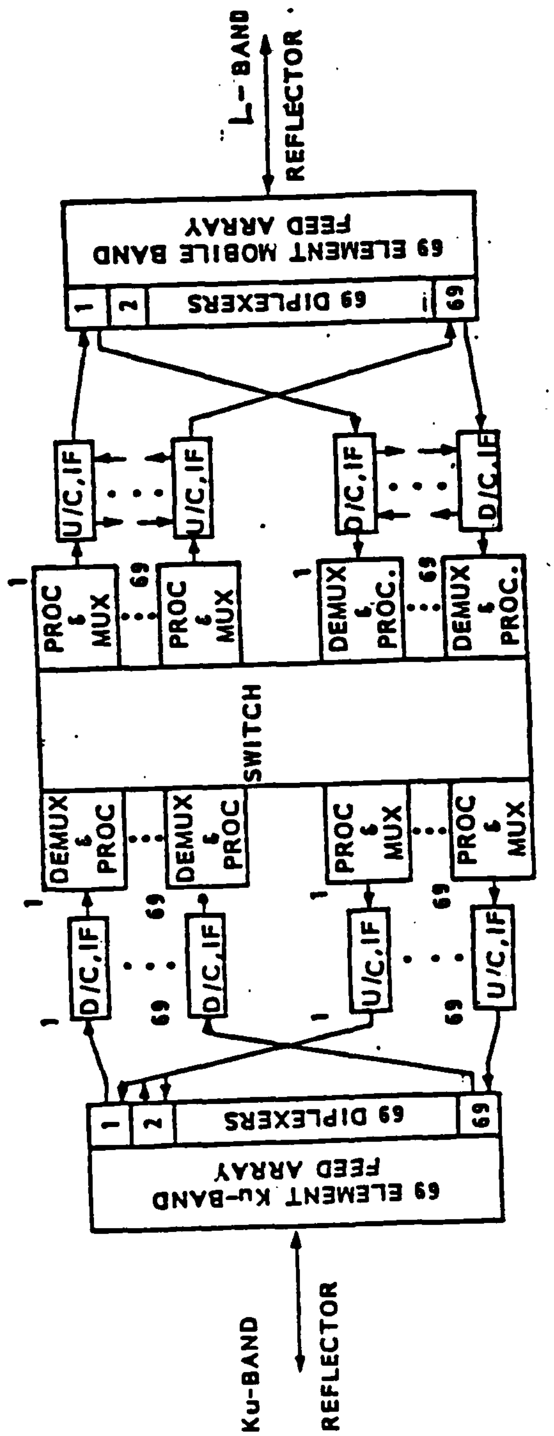

Figure 55

and a service grade probability of 2 percent blocking comes to 95 Erlangs. It is further assumed in this deviation that calls not immediately satisfied are cleared and do not reappear during the period under consideration.

Assuming an average duration of 120 seconds per call, 95 calls can be satisfied in one foot print every 120 seconds, or 2850 calls maximum per hour. The total instantaneous capacity of the system is 196,659 for all 69 beams. However, the traffic will not be homogenously distributed so that the peak capacity would be lower. Further traffic distribution analysis would be required to get a more accurate system specification.

Spacecraft Technical and Weight Estimates

The General Electric study describes the satellite power requirements at the L-band to be 48 kilowatts, with an L-band antenna of 70 feet in diameter. Figure 56 gives the spacecraft technical characteristics and Figure 57 gives the weight estimates. A conservative cost of such a satellite system in the late 1980's is $58 million/year not including user equipment costs. In the year 2020, both the high-power and the satellite switch will be significantly lower in cost if the assessment of technology growth assumed is realized. This concept is based on compatibility with current terrestrial mobile terminals. If for ATC the mobile terminals have higher radiated power and lower receiver nose figures, the satellite power and cost can be further reduced. Analysis of these alternatives are not within the scope of this report.

Spacecraft Technical Data

Payload	
Forward Transponder	69 Parallel Redundant Units Ku-band to Ku-band Frequency Conversion
Return Transponders	69 Parallel Redundant Units L-band to Ku-band Frequency Conversion
Transponder Type	Double Frequency Conversion
EIRP per Voice Channel	45.2 dBW
EIRP per Beam (Transponder)	65.7 dBW
Number of Beams	69
Voice Channels per Beam	111
Antenna Gain	44 d Bic - At Corner of Cell
RF Radiated Power per Beam	21.7 dBW, 148 Watts
G/T	16.4 dB/^{o}K
Bandwidth per Beam	10 MHz each way
L-band Antenna	
Type	Offset Parabolic Reflector Multibeam, F/D = 1
Effective Aperture	75 ft Diameter
Spacecraft	
Size	15 ft L, 9 ft H, 15 ft W
Weight	5515 lbs
Electrical Power S/S	41 kW Array Power 5130 ft^2 Solar Array
Thermal S/S	1200 ft^2 Radiating Surface

Figure 56

Spacecraft Weight Estimates (Pound)

		L-band
Mobile Band Antenna		
	- Reflector	250
	- Supports	125
	- Feed Array	160
Transponder		
	- Mobile Band Diplexers	35
	- Mobile Band Power Amplifiers	140
	- IF Components	100
	- Ku-band Power Amplifiers	15
	- Ku-band Diplexers	15
	- Cabling	50
Ku-band Antenna		
	- Reflector (solid)	35
	- Supports	10
	- Feed Array	5
Spacecraft Structure		700
Propulsion		1200
Electrical Power Subsystem		
	- Solar Array	2100
	- Electronics	75
	- Battery	450
TT&C		50
	Estimated Weight-pounds	5515

Figure 57

Avionics

The aviohics will be a straightforward FDM/FM unit as shown in Figure 58 together with a voice input. The system is likely to include data transmission. The typical cost of such an avionics unit should be no more than today's VHF two-way voice unit, which is in the range of $1,000 to $2,000. However, the quality of the proposed FM will be significantly superior to the current AM system. The characteristics of the avionics for this system concept are the following:

Signal quality:	50 db subjective S/N minimum
Coverage:	Whole of CONUS to all altitude levels where aircraft can safely traverse
Modulation:	Frequency modulation with $12KH_3$ deviation
Channels:	30KHG bandwidth at L-band ($1500-1600MH_3$)
Receiver Nose	
Temperature:	546^{o}k
Transmitter Power:	10 watts
Aircraft Antenna:	Omni-directional gain of 4dBIC

The 50db S/N ratio is obtained by use of emphasis circuits and compounding. The system concept could easily be modified to digital voice employing Continuously Variable Slope Delta Modulation (CVSD).

d. Conclusions

The high traffic growth forecast for the rapid growth scenario will bring about major changes to the current surveillance,

Air-Ground Voice Avionics

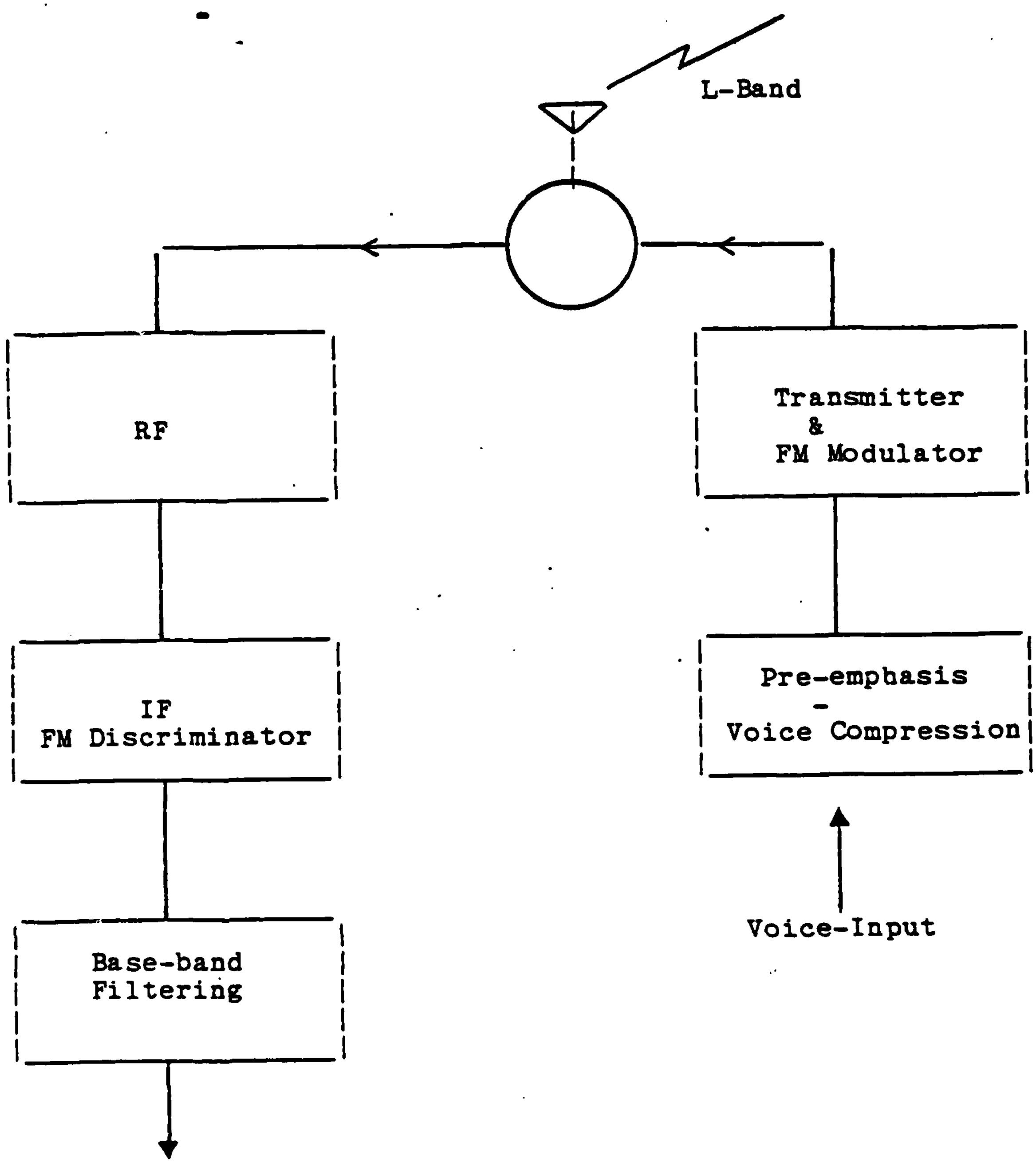

Figure 58

navigation and communications system. Fortunately, in this scenario, there will also be a major growth in technology and telecommunications. Consequently, the availability of a completely space-based system for ATC functions is forecast for the year 2020. The cost-effectiveness and increased coverage of the space-based system will be the reason for its implementation. In such an environment, aviation communication is separated into a trunking communication service between the major ATC ground stations and air-ground communications.

The trunking service between the relatively few facilities, which are still likely to be distributed over CONUS, is assumed to be served by commercial domestic communications satellites. However, for the air-ground voice communications, a separate satellite concept is presented. Evolution of such a system is expected to develop from MARISAT, an Oceanic Satellite ATC system such as Aerosat, and other concepts currently being developed for a land-mobile telephone system.

Hybrid Terrestrial and Space Based ATC System: Balanced Growth Scenario

In the balanced growth scenario the traffic growth is gradual, with sufficient time available to expand gradually the performance and capacity of the ATC system. Central to the balanced growth scenario will be the two systems: (1) GPS for navigation and (2) for surveillance, ground-based DABS with satellites aiding in the expansion of coverage and transition to a future space-based surveillance system.

a. System Concept

A satellite based navigation will remove the 1000 VOR/TACAN/DME sites, communication requirements to and from those sites, and the frequency allocated to VOR and TACAN/DME. Elimination of VOR together with ILS would also impact upon the Flight Service Station network and VHF voice. The advantage of L-band for satellites versus VHF would indicate the desirability of switching to L-band for air-ground voice. However, as the technology advances are less than in the rapid growth scenario, the air-ground voice would be mainly terrestrially-based with a less complex satellite providing coverage in areas outside the terrestrially-based stations.

The advances in computational capability, sophisticated displays, and further automation will allow centralization of the ARTCC's and Flight Services, Flow Control, and FAA maintenance and operations. Weather information would be centrally processed and disseminated by the DABS data link and the air-ground voice communications to aircraft.

The terrestrial components of the DABS surveillance system would be deployed in the major hub areas, mainly at terminals. Satellite surveillance compatible with terrestrial DABS would fill in the remaining coverage areas. To accomplish this the satellite would have to be powerful enough to satisfy the aircraft's DABS transponder receiver, and the satellite receiver would have to be able to pick up the DABS transponder transmissions.

Ground-to-ground communications with space-based GPS and satellite-aided DABS would require communication links from DABS facilities to the ARTCC's and TCC's, in addition to the other centers. The monitoring of terrestrial facilities for reducing costs of operations, maintenance, certification, etc. would involve significant use of data collection platforms, as in the space-based scenario, where data is collected by a satellite transponder. The growth of these platforms for many other monitoring purposes, such as environmental monitors, weather data sensors, ocean bouys, inaccessible military facilities, etc. would result in a variety of commercial offerings. The value of data collection platforms in this scenario is even more important than in the space-based scenario due to its cost-effectiveness. Figure 59 describes the major elements of the Hybrid ATC System.

In the 1990's the ARTCC and FSS are expected to consolidate into a single facility. By the year 2020, further centralization of the 20 or so CONUS ARTCC/FSS into, at most, 2-5 facilities would result in longer distance communication links between DABS, TCC's and other terminal facilities to the ARTCC/FSS facilities. Commercial satellite services are likely to be the most cost-effective for ground-to-ground data and voice communications. However, the system would be optimized to cost-effectively integrate terrestrial tails from the satellite earth terminals. Availability and reliability would be maintained by appropriate space-segment back up and selected narrow-band terrestrial links.

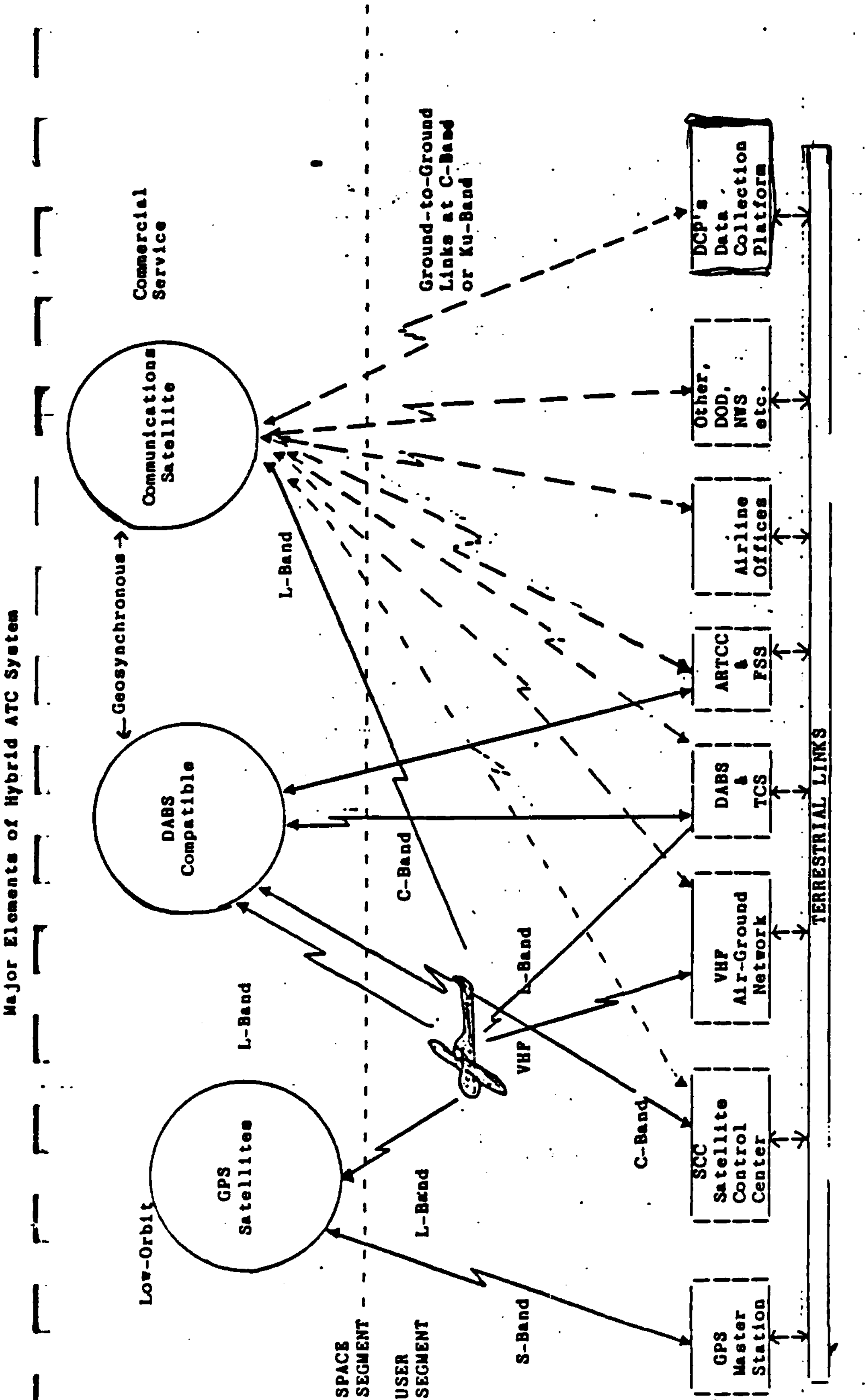
Major Elements of Hybrid ATC System
Commercial Service
Communications Satellite
Geosynchronous
DABS Compatible
Low-Orbit
GPS Satellites
SPACE SEGMENT
USER SEGMENT
Ground-to-Ground Links at C-Band or Ku-Band
L-Band
C-Band
VHF
S-Band
DCP's Data Collection Platform
Other, DOD, NWS etc.
Airline Offices
ARTCC & FSS
DABS & TCS
VHF Air-Ground Network
SCC Satellite Control Center
GPS Master Station
TERRESTRIAL LINKS

Figure 59

By the year 2020, the Domestic Satellite Communications Carriers will have their satellites either linked by intersatellite links or contained on the same large platform with other carriers. This will give a significant increase in space-segment availability for all users of satellite communications.

The consolidation of ARTCCs with FSS will result in increasing internal communication systems within facilities. Fiber optics and efficient data and voice coding methods will find widespread use. Similarly, communications requirements between facilities in the terminal area will increase support, thereby increasing automation in maintenance, monitoring, controller workload, etc.

b. Surveillance

The development of the surveillance system concept is beyond the scope of this task. However, it is useful to define the basic concept implied in the satellite-aided DABS. The need to provide increased coverage within a fixed budget will provide incentives to adopt a satellite system by 2020. An objective of the satellite system is to reduce the number of terrestrial DABS sites from 300 to about 50-100 planned sites. These DABS sites would be located in high density areas. Satellite surveillance would be provided in less dense geographic areas. The surveillance and data link SD satellite will have fewer beams and lower capacity than the full CONUS coverage system described in the previous section.

In areas where DABS coverage is not available, position information for surveillance would be based on GPS. The coordinates of the terrestrial and space systems would be calibrated. In addition, the SD satellite would be used to connect all DABS stations to the ARTCCs and TCCs. The data link formats would be the same for both the terrestrial and space links.

At present, all terrestrial surveillance and data link system concepts have been planned and are summarized in the Phase III report. As noted above, this system includes 300 DABS sites which will be connected with the ARTCCs, TCCs, etc. The terrestrial system requires more data communications capacity than the satellite-aided DABS. However, this mixed system may then be considered as a transition state betwen the terrestrial system and an all space-based system. As such, the system would be likely under the Balanced Growth Scenario.

c. Communications Subsystem for the Hybrid/Terrestrial Concept

The communications subsystem, as noted in the space-based concept, includes the following major elements:

1. Air-ground communications;

2. Ground-ground communications between major centers and terminals;

3. Ground-ground communications within facilities and major and medium hubs;

4. Communications to data collection platforms (DCP's).

Air-ground voice communication will use primarily VHF. The use of VHF will embody increased use of digital voice coding and improved

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efficiency of spectrum use. However, high performance users such as air carriers will be offered satellite communications by commercial carriers. The satellite-to-aircraft links will be at L-band requiring a separate L-band RF section for those users. Such a system would require a less complex satellite than described in the Rapid Growth scenario. The likelihood of two air-ground communication systems existing is reasonable since the economic returns from improved communications to the air-carrier and other high performance users will be significant. Another basis for this forecast is the assumption that oceanic ATC communications via satellite will be operational by the year 2020, so for many of the carriers there may be no additional investment required.

The terrestrial VHF towers could also be connected via satellite to an FAA central facility. There are 3 subsystems for air-ground communications in this scenario:

- ATC data-link on DABS;
- L-band/KU-band satellite for high performance users;
- Terrestrial based VHF, with satellite link-up towers.

The satellite communication subsystem is given in the next section.

Ground-to-ground communications between major terminals will be provided as both commerical carrier satellite and terrestrial links. Standardized configurations would exist for major nubs, medium hubs, and small terminals. Intrafacility communications is a highly dynamic and innovative industry and maximum opportunity should be taken in

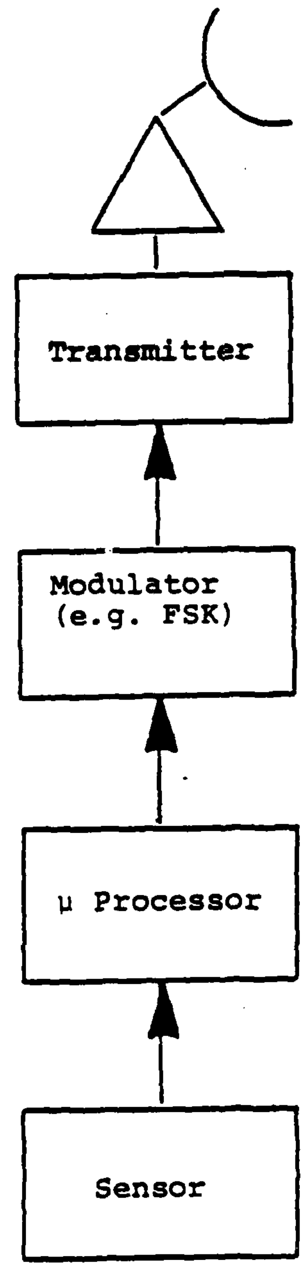
reducing costs and performance of facility operations. As such, communications will be expanded with transmission by fiber optics.

DCP's are basically composed of a sensor and a transmitter. The satellite picks up the data from the sensors and transmits it to central locations. Today non-military DCP's use is in global environment and earth observations, with data being relayed by the weather and land satellites. These platforms transmit at 400 MH with data rates up to 5 KBPS at 3-10 hr. intervals. DCP transmitter power is less than 5 watts. Monitoring for maintenance and certification could be easily satisfied within an order of magnitude of these specifications. With use of geosynchronous satellites, continuous monitoring of critical facilities could be maintained. A block diagram of a typical DCP is shown in Figure 60.

d. Satellite Subsystems for Air-Ground Communications

This section briefly describes the air-ground satellite communication for air-carrier and other high performance users and the use of a satellite for linking the terrestrial VHF towers. An air-ground communication satellite concept derived from a COMSAT study of 1978 is shown in Figure 61. This satellite concept is less advanced than the design described in the Rapid Growth scenario. However, the design represents the current state-of-the-art and is being proposed as a new initiative for COMSAT in the 1980's. In this COMSAT design, a 22 beam satellite is proposed, employing TDMA with digital modulation, which could use CPSK, DPSK or FSK. The voice

Typical Data Collection Platform
for Monitoring ATC Facilities



Typical Data Collection Platform

Figure 60

Air Ground Satellite Communications Concept
Derived from Preliminary Study by COMSAT

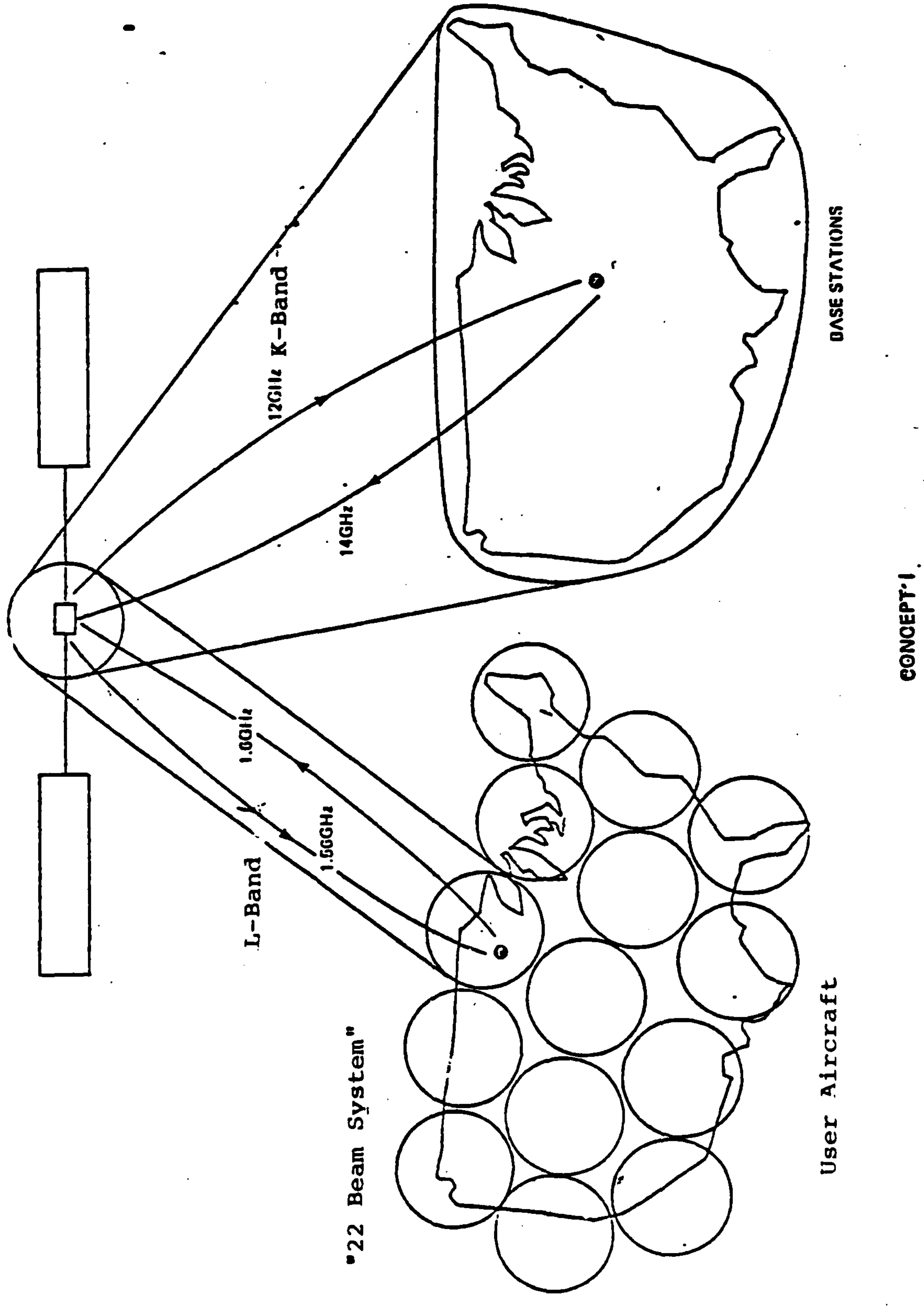


Figure 61

processor has a rate of 16 kbps using CVSD (continuously variable slope delta-modulation) or could use adaptive PCM. The resulting voice intelligibility should exceed 95% with a bit error rate of 10^{-4}.

A block diagram of the avionics for the satellite transponder with onboard switching is shown in Figure 62. The corresponding block diagram of the user base stations is shown in Figure 63. The costs of the avionics and the base stations were estimated at $3,000 and $55,000 respectively in the COMSAT study. Each user group would have its own base station. The cost estimate of the 22-beam satellite system was $24 million annually. Technology forecasts indicate significant reduction in these costs by the year 2020. The economics of scale and a 40-year learning curve should result in similiar user costs for a "satelliteradio" or "terrestrial VHF-radio".

The user cost estimates are given in Figure 64, while the satellite mass budget is given in Figure 65. The satellite cost based on the mass budget is $26 million; this figure does not include development costs, and assumes procurement of multiple satellites. The average life time of the satellite is 7 years. The costs of the avionics is based on a production of 5,000 units, and the base-station costs were derived from current trends in earth terminal costs.

The satellite antenna is the same size as the ATS-6, i.e. 30 ft; the base station dish is 15 ft. and the aircraft antenna can be dipole with a 3dB gain.

Avionics Block Diagram
Derived from Preliminary Study by COMSAT

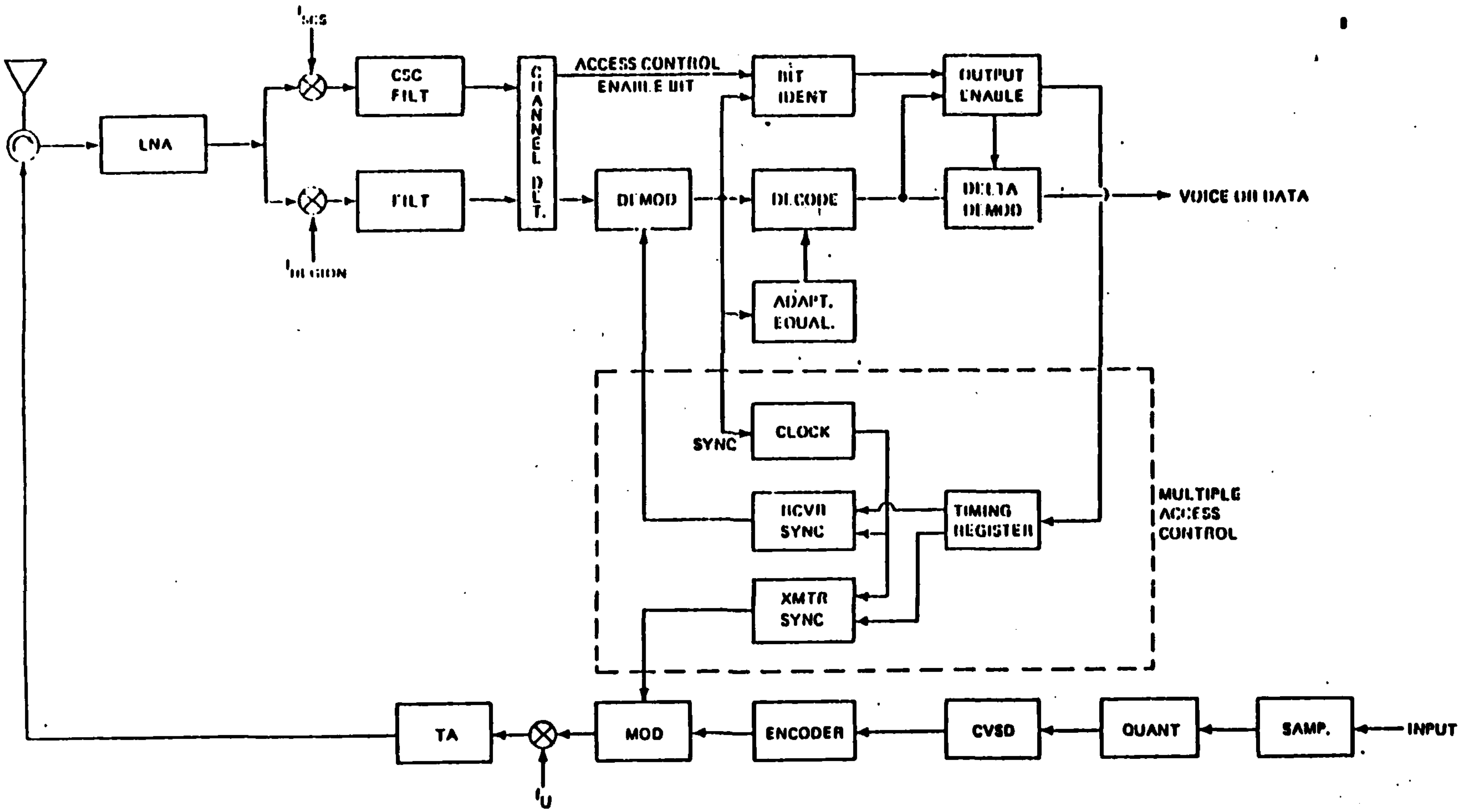


Figure 62

Base Station Block Diagram
Derived from Preliminary Study by COMSAT

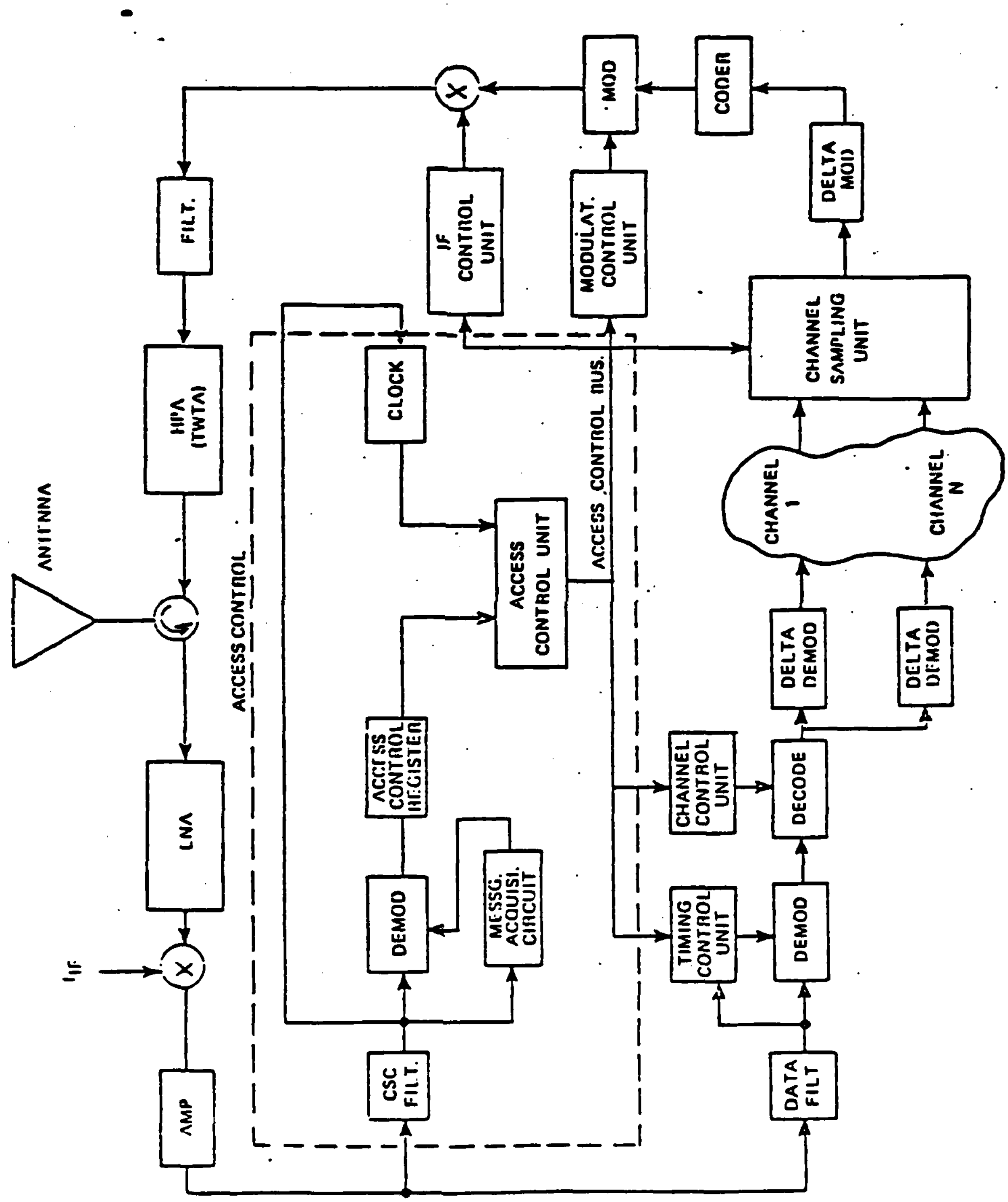


Figure 63

User Cost Estimates for Avionics **

COMPONENT	MOBILE TERMINAL		FIXED BASE STATION	
	DESCRIPTION	COST	DESCRIPTION	COST
HPA	20 Watt Transistorized power amplifier*	$400	20 Watt TWTA	$2,000
LNA	400° transistorized amplifier*	$100	Uncooled 1000° GaAs FET Amplifier	$5,000
MODEM	PSK 1 Mbps modem with timing, synchronization and carrier recovery	$1200	PSK modem similar to mobile unit	$8,000
CODEC	Adaptive 1 Mbps † Viterbi channel equalizer	$500	Optional	----
VOICE PROCESSOR	16 kbps CVSD*	$50	Paralleled 16k bps CVSD units	$500
ANTENNA	3 db dipole*	$20	5m parabolic non-tracking center fed	$10,000
ACCESS	Word synchronized, acquisition and end of message control	$800	Centralized or distributed	$27,000
	TOTAL COST	$3070		$54,000

* Based on COMSAT Study
** All costs are in 1976 dollars

Figure 64

Summary of Spacecraft Mass Budget
(COMSAT Study)

		Kilogram
1.	Structure & Separation	150
2.	Reflector	162
3.	Transponder (RF & Signal Processor)	86
4.	Electrical Power	90
5.	Attitude Control	70
6.	Propulsion	74
7.	Thermal Control	30
8.	Telemenetry & Command	20
	Total (kg)	682

Figure 65

e. Satellite Repeater for VHF Towers

A sketch of the Satellite repeater concept is shown in Figure 66. The aircraft communicates to the VHF towers. A repeater transmits the signal at S-band to a satellite which then connects to the base-stations at KU-band. The number of S-band beams would be much lower than the L-band case since the repeaters could have a much higher power level. A block diagram of a repeater from the COMSAT study is provided in Figure 67.

Terrestrial Navigation, Surveillance and Communications System: Stagflation Scenario

a. Overview of ATC Configuration

A stagnant economy with high inflation will not be able to afford extensive structural changes in the ATC system. High costs of energy, in addition, will prevent any major increase in aviation activity from the levels forecast for the 1990's. Aviation communications being planned for the 1990's are likely, therefore to be the configuration of the system for this scenario. With the limited resources of stagflation budgets, the total ATC system will be a patch-up of different generation subsystems. GPS will be used by the military, TACAN will be phased out. However, civil navigation will stay with the 1000 VOR/DME facilities. DABS will reach its planned 300 facilities. However, some ATCRBS sites may continue to exist and, hence, some users would continue to fly with current transponders with limited data link capability. The number of ARTCC facilities in CONUS will continue at about 20. Flight Service Stations at major hubs will have been consolidated

Satellite-Aided VHF Air-Ground Communication

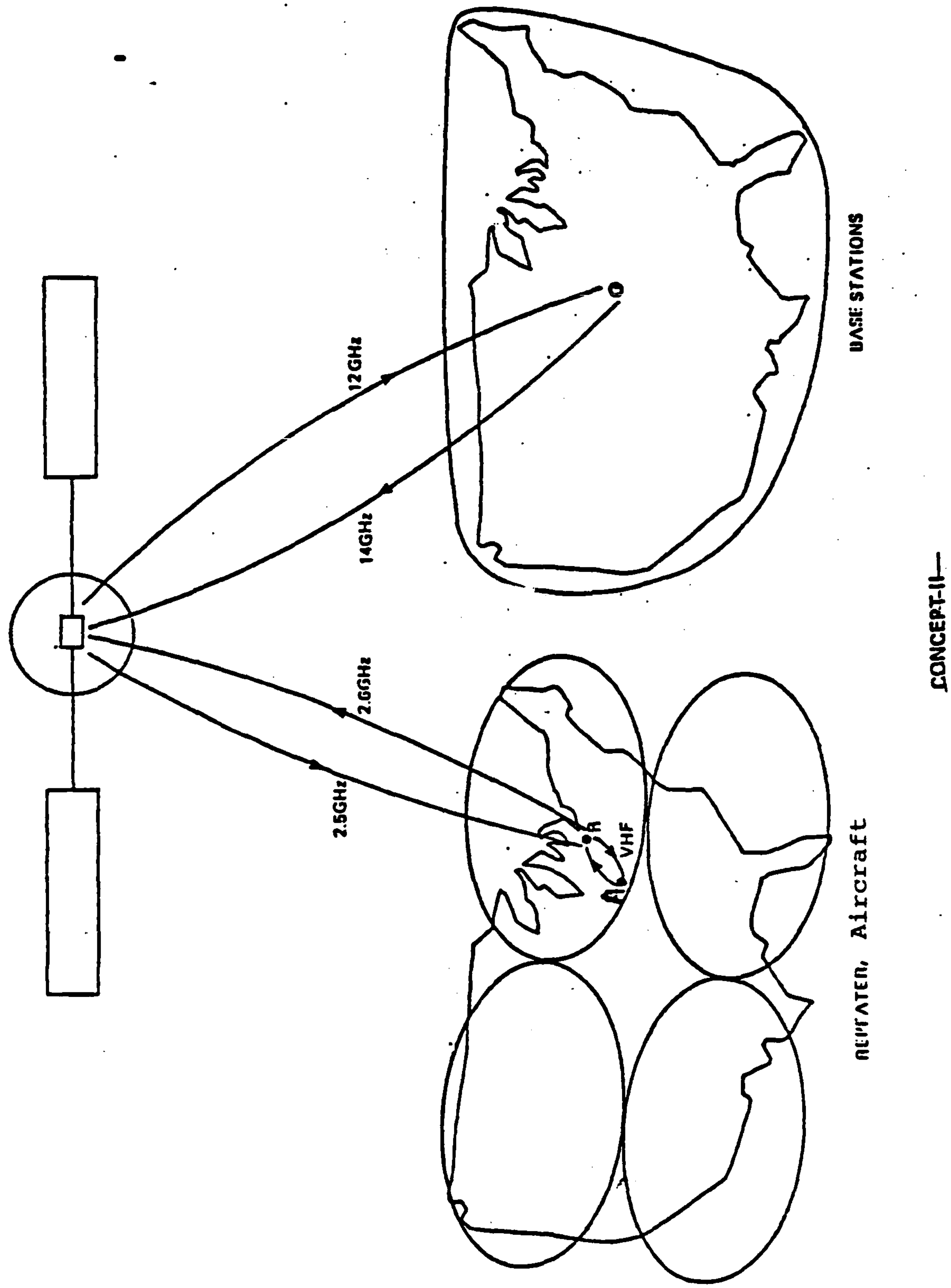


Figure 66

Repeater Block Diagram

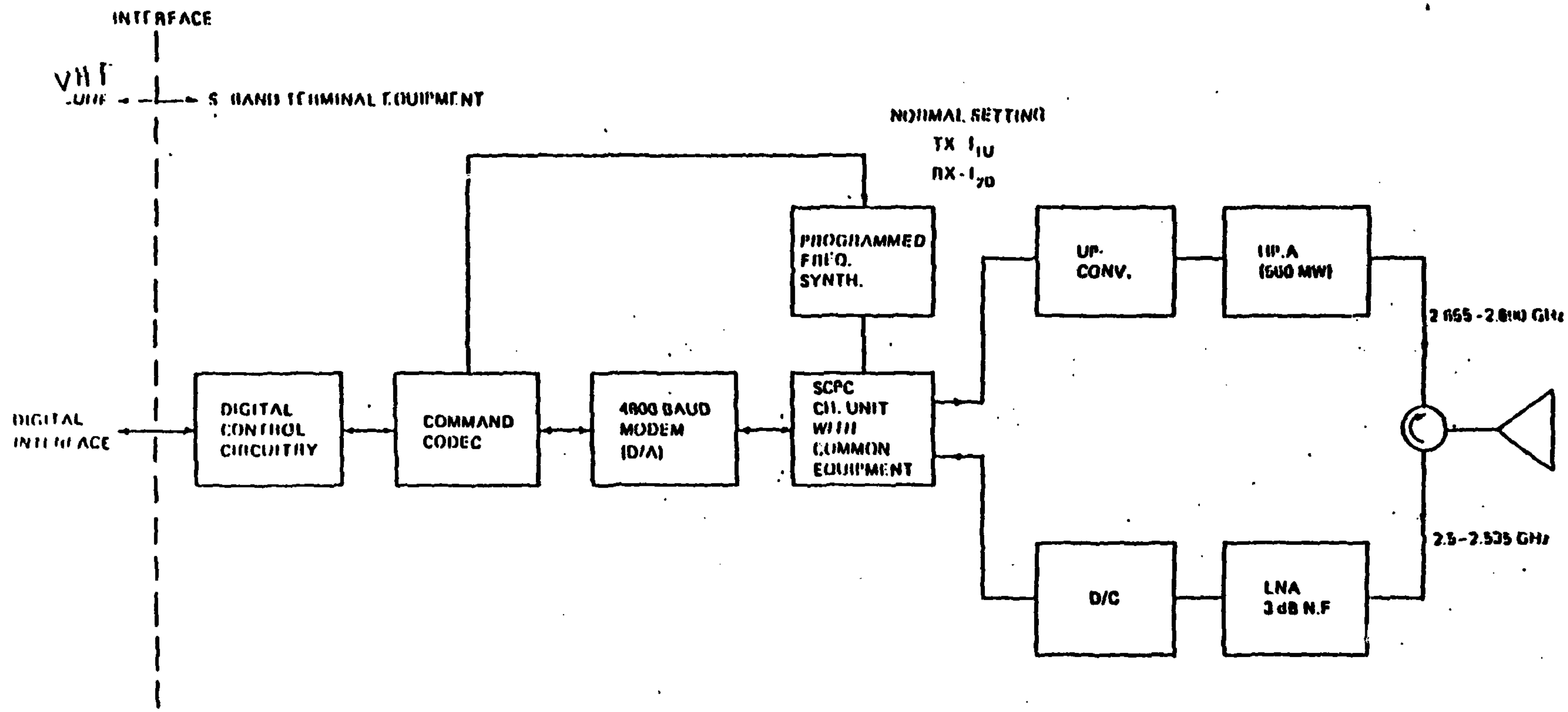


Figure 67

with the ARTCCs, but many smaller non-automated and automated FSS's would continue. Ground-to-ground data communications will be within NADIN (National Data Interchange Network), it being essentially the 1990 configuration planned for Phase III. The communications common carriers will have significant influence in integrating the ATC communication subsystems in data and voice and ground-to-ground and air-to-ground. In addition, current tube equipment will be replaced first with solid-state units and then with LSI digital circuitry, with emphasis on automated facilities with the capability for remote maintenance monitoring and remote fault diagnostics and certification. In the air-to-ground voice systems, there will continue to be numerous facilities distributed over CONUS. Figure 68 gives a list of major installations that currently exist and that are likely to remain the same in this terrestrial scenario. An overview of the ATC configuration for this scenario is given in Figure 69, based on the 1990 configuration of current plans. The shaded parts indicate the system improvement and additions from the current system. The data and voice communication system are further described in the following section.

b. Data Communications Subsystem

All data communications will be integrated under NADIN as shown in Figure 70. NADIN allows any user to communicate with any other user through the use of data concentrators and two centrally located switches. By the year 2020, the likely evolution of NADIN will be a satellite switched service directly from the NADIN data concentrators.

Summary of FAA Facilities
Containing Communications Equipment

FAA FACILITY	NUMBER OF FACILITIES (1974)
ARTCCS (Foreign and Domestic)	27
TRACONS	174
TOWERS	438
FSS Stations	327
RCAG Sites	412
BUEC Sites/LRR Sites	95
VOR/VORTAC Sites	1,000
RCO Sites	54
LRCO Sites	533
DF Sites	277
NATCOM (Kansas City, Mo.)	250 Estimated
SCC (Washington, D. C.)	1
NFDC (Washington, D. C.)	1
NAFEC (Atlantic City, N.J.)	1
OKC (Oklahoma City, OK)	1
Regional Offices	12 Includes Alaska and Europe

Based on ATS Fact Book, December [illegible]74

Figure 68

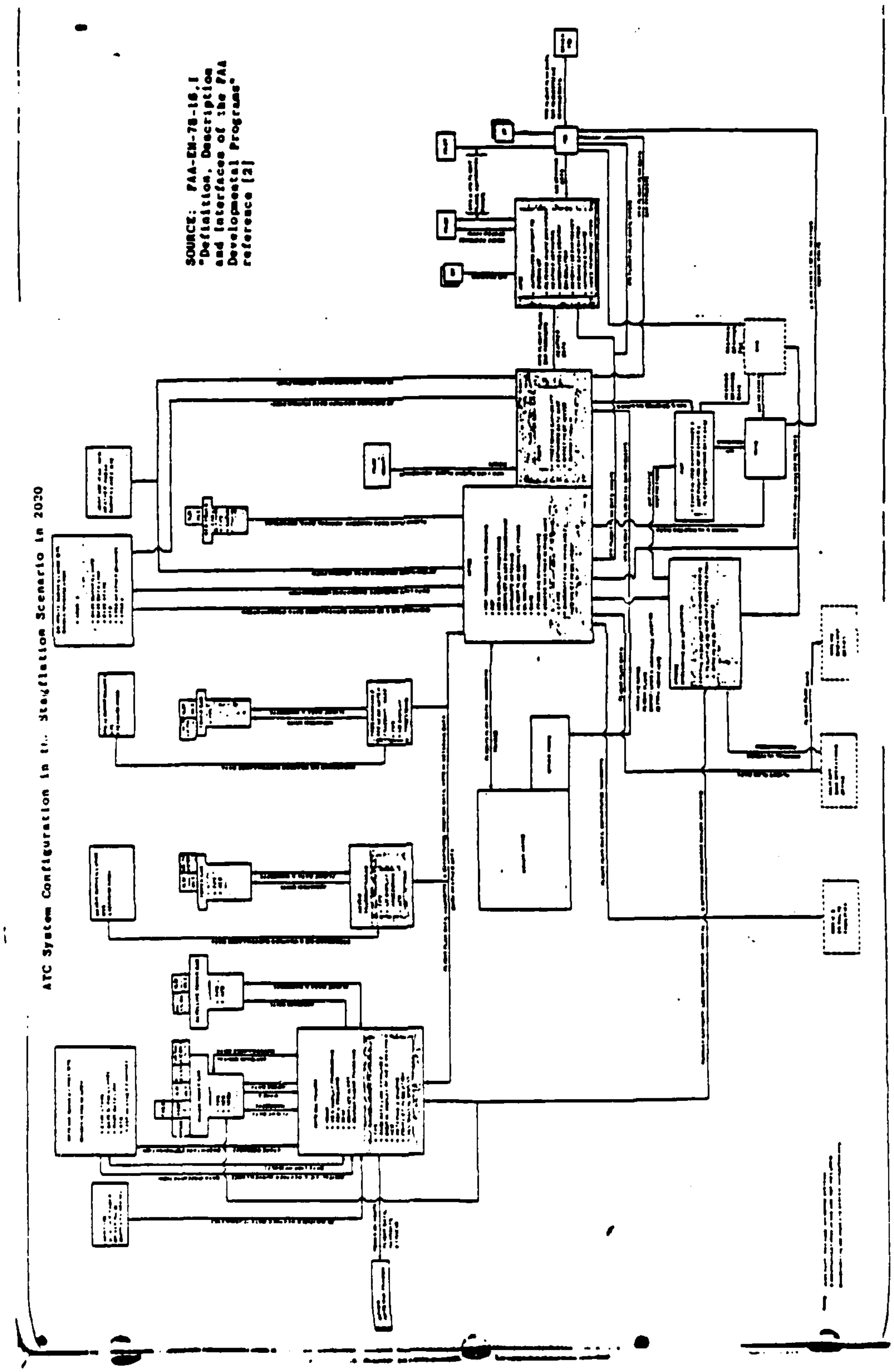

ATC System Configuration in the Stagflation Scenario in 2020
SOURCE: FAA-EM-78-18,I
"Definition, Description
and Interfaces of the FAA
Developmental Programs"
reference [2]

Figure 69

Project 1990 Data Communications System
for the National Airspace System
(Source: FAA-EM-78-16)

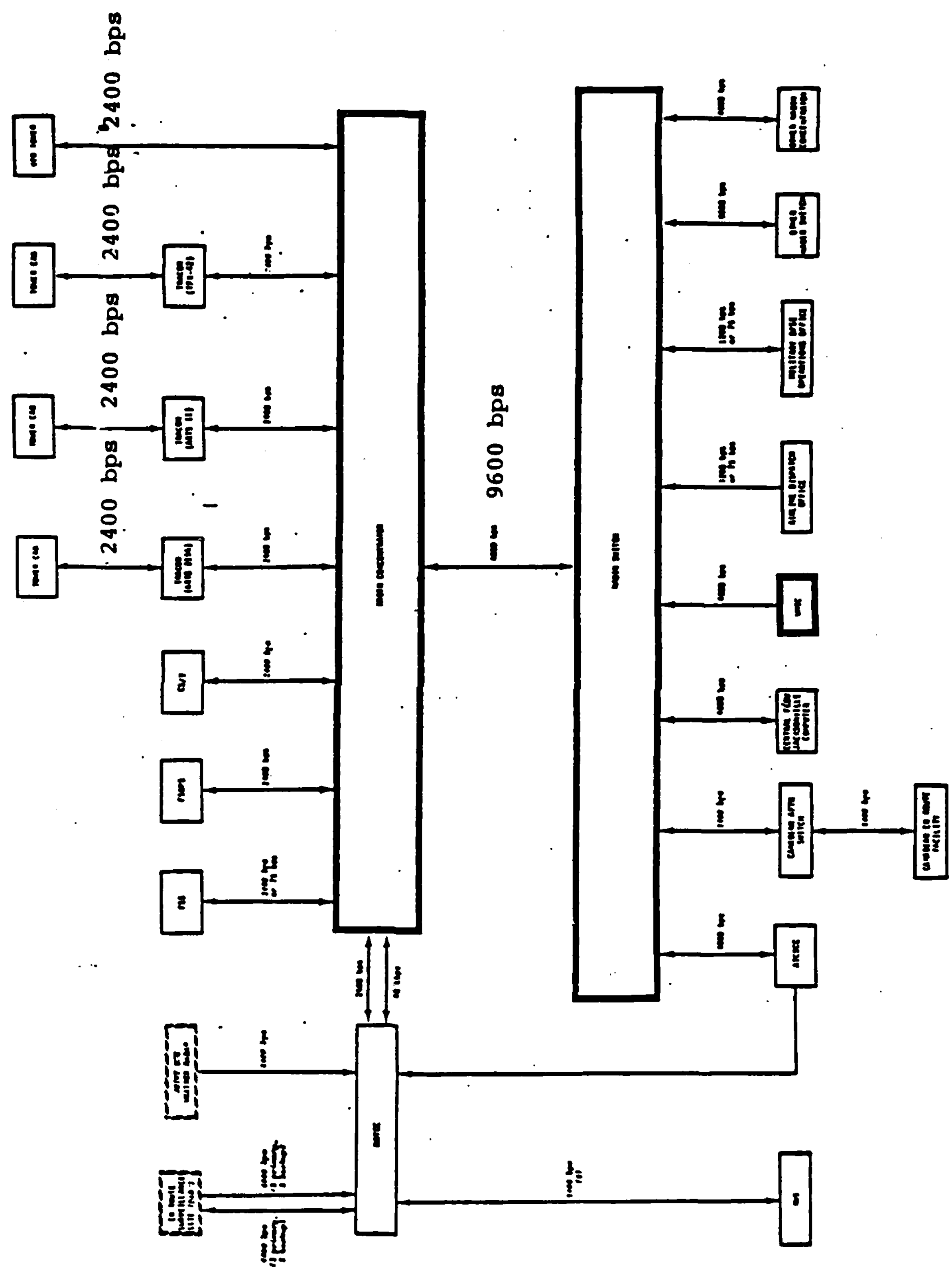


Figure 70

Figure 70 illustrates the NADIN connectivity and data rates assumed at the time of NADIN Phase III completion. NADIN provides communications between the enroute centers and terminal areas. There will be a number of NADIN concentrators, one located at each ARTCC with exchanges at Anchorage, Honolulu, and San Juan. The ARTCC has a wideband 40 kbps link to the concentrator and narrow band 2,300 bps links. The nationwide network connecting the concentrators to the NADIN switch requires only 9,600 bps link. All other links are also 4,800 bps, or lower, as shown in Figure 70. In the case of a satellite switch connecting to the NADIN concentrators, it would have a back up satellite and some terrestrial links.

The NADIN system is being designed to interface with all kinds of transmission media, including satellites, for domestic and international communications. Thus, the transition to a satellite link directly from the NADIN concentrators will be feasible. In addition, the NADIN design will be transparent to the users in that it will requre no changes to data handling protocols or practices. The NADIN system has been described in considerable detail in the technical appendix of the Phase I report.

c. Voice Communications

The voice communications network structure planned for 1990 will not change significantly by the year 2020 in the stagflation scenario. The air-to-ground voice communications will either operate through FSS's or ARTCC and TCC's, while the Service F network will interconnect between terrestrial facilities.

Figure 71 shows the expected connectivity of the voice communication system. The current electromechanical switching systems, consisting of the WECO 300 at the ARTCC and the WECO 301 at the terminal areas, will have been replaced by the Voice Communications and Control Svstem (VSCS), which has an integrated air-to-ground and ground-to-ground voice concept. This program consists of three ingredients: first, the RCAG tone control replacement; second, the Radio Communications Control System (RCCS); and third, the Ground Voice Communications component.

Airline communications will also be mainly VHF, with increasing use of digital voice and coding for privacy. Some of the air carrier's larger craft may start using satellite links for airline communications as described for the hybrid scenario. However, in general, there will be little incentive to invest in higher performance communications in this scenario than those shown in Figure 65.

d. Conclusions

In the stagflation scenario it is difficult to see structural changes to the NAS system other than those currently projected for 1990. The major system changes are the implementation of DABS, GPS for the military, and VOR/DME for civil navigation. Data communications will evolve only slightly from NADIN Phase III. The change would be, possibly,in the elimination of the two terrestrial switches by a satellite switch and backup satellite. Air-to-ground voice and ground-to-ground voice configurations would not change, except for fewer electronics, better and higher gain antennas, and increased use of microprocessors, etc.

Projected 1990 Voice Communications System
for the National Airspace System
(Source: FAA-EM-78-16)

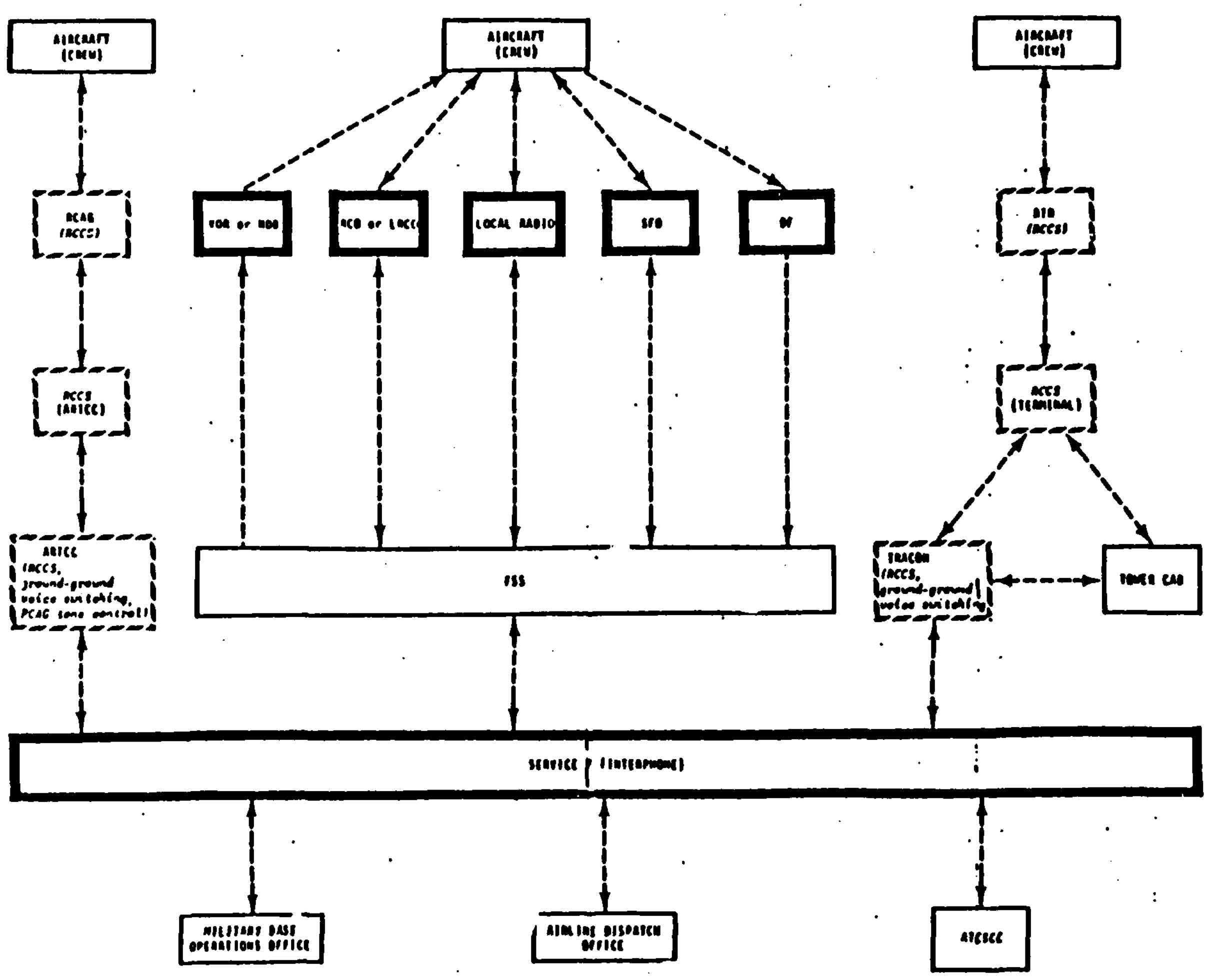


Figure 71

IMPACT ASSESSMENT SUMMARY

This study was undertaken to identify and examine the likely effects of future aviation communications technology. The assessment is based upon and constrained by the technology forecast and socioeconomic scenarios - stagflation, balanced growth and rapid growth. Both the technology forecast and socioeconomic scenarios limit the extent and magnitude of effects, because the impacts are a function of social and technological conditions. The two primary factors considered in the assessment are agency capital and labor. The extent to which future technology is likely to be labor saving will be a function of the capital investment level, the efficiency of that capital and the future scenario in which the capital will function.

Technology has been defined as the knowledge or set of physical objects that allow a "want" of man to be attained. The impacts of technology derive from function and operation. The non-human performance of function requires that a technology operate. The act of operation requires the consumption of resources and generation of by-products. In the act of operation, the technology has certain effects due to its function and certain effects which emanate from its being. The effects of function refer to the purpose of technology in its societal context while the effects of operation refer to the consequences of a technology's being. The demand for technological application is a derived demand since the perceived need for technology occurs due to demand for some other form of goods and services.

The initial effect of technology would be to diminish man's role in the performance of specific functions. Changes in the division of labor between man and machine would depend upon the current functions of man and machine as well as changes in the level or nature of the functions performed. As the man-machine division of labor changes so does the relative composition of the factors of production. The net and measurable effects of technological change are:

1. a change in the level and nature of agency capital investment;
2. a change in the magnitude and composition of the agency work force.

In general, two groups will be impacted by the adoption of new aviation communications technology. First, users of the airspace system including pilots and aircraft owners. Second, managers of the airspace system including FAA operators and management personnel from ATC, ATF and FSS. The effects of new technology will derive from the functions performed and/or needed by the airspace users and managers. The magnitude of effects will depend upon the extent to which new technology usurps existing or creates new functions.

The evolution of new aviation communication technology will not alter the system functions that need to be performed. Rather, technology will change the way in which such functions are performed. As such, new technology will not only change the man-machine division of labor but will also decrease the time attendant to each function. New technology will significantly change agency staff and capital

as follows:

1. increased substitution of capital for labor;
2. increased capacity in terminal and enroute airspace; and
3. impacts due to the operation of the technology.

The three industries considered in this study and the measures of product are as follows:

Three Components of the Airspace System (Industry)	Measures of Product
Terminal Areas	Annual Aircraft Operations
Enroute Centers	Aircraft Handled
Flight Service Stations	Contacts

The effects of new technology can be estimated using the production function construct. The production function estimates the relationship among industry product and the factors of production. Estimates of the present production function coefficients are obtained from existing agency data and are then modified based on the estimated change in the efficiency of the technology. The new technology production function coefficients can then be employed to estimate the shifts in labor or capital attendant to the new technology. Major impacts of communications technology can be measured in terms of personnel or capital requirements. The Tinbergen formulation of the Cobb-Douglas production function was used to estimate the magnitude of such impacts. The data for estimating industry capital and labor requirements exist in the form of forecast variables under each scenario. The Tinbergen model is as follows:

$$Q = AK^{\alpha} L^{\beta} e^{yt}$$

where:

Q = product
K = capital
L = labor
t = time
A, α, β, y are empirically determined coefficients.

The two major components of the airspace system are:

1. terminal areas (used by general aviation, air taxis, commuters and corporate aircraft, as well as air carriers.)

2. enroute airspace (used predominantly by air carriers, commuters and corporate aircraft).

Separate production functions are estimated for each component of the airspace system. Also, two sets of production functions must be examined for each portion of airspace: system users and providers of service.

The user production function in the terminal area is:

$$TOPS = A(TCAP)^{\alpha} \; (TPLT)^{\beta} \; e^{yt}$$

where,

TOPS = Total Operations = Local Operations + Itinerant Operations;

TCAP = Active general aviation fleet and air carrier fleet capital;

TPLT = Total pilots active in the terminal area.

The agency production function in the terminal area is:

$$TOPS = A \; (CTERM)^{\alpha} \; (TERM)^{\beta} \; e^{yt}.$$

where,

TOPS = Total Operations = Local Operations + Itinerant Operations

CTERM = Capital = the consumed value of agency communication facilities in the area.

TERM = Labor = the array of government personnel, primarily controllers, necessary to manage TOPS.

The user production function for enroute airspace is:

$$\text{AIRHAND} = A(\text{TACAP})^{\alpha} \ (\text{TRANP})^{\beta} \ e^{yt}.$$

where,

AIRHAND = aircraft handled

TACAP = aircarriers fleet capital

TRANP = number of transport pilots

The agency production function for enroute airspace is:

$$\text{AIRHAND} = A(\text{CCENT})^{\alpha} \ (\text{CENT})^{\beta} \ e^{yt}$$

where,

AIRHAND = aircraft handled

CCENT = agency capital = the consumed quantity of technology necessary to service AIRHAND

CENT = agency labor = the number of agency personnel necessary to perform center functions.

The basic assumption concerning ATC facilities and equipment under the stagflation scenario is that no radical new technology is introduced. Conventional technologies and their improvements will determine the shape of the ATC system during the forecast period (1980-2020) and the growth in the replacement values of ATC facilities and equipment will slow down in relation to growth in GNP. Under these assumptions, capital consumption has been projected to grow in the stagflation scenario from $275.1 million in 1980 to $1329.0 million in 2020. The increase represents an annual compound growth rate of 4%.

Capital growth for the stagflation scenario has been projected for the period 1980 to 1990 by estimating, first, additions to terminal facilities to match demands upon airport capacity and, second, improvements in facilities and equipment throughout the ATC system.

The FAA has forecast the number of airports that will exceed their operating capacity over the next decade and these forecasts form the basis of the additions to terminal capacity from 1980 to 1990. Increases in terminal area facilities will be accompanied by increases at enroute centers and flight service stations to provide for larger volumes of traffic. For example, from 1975 to 1979, en route center facilities and equipment replacement values increased on average at 89% of the rate of growth of capital in the terminal areas. Growth in flight service station facilities and equipment replacement costs were 221% of the growth of terminal area capital investments for the same years. Therefore, it has been assumed that each 1% increase in growth of terminal area capital from 1980 to 1990 will be accompanied by a 0.89% increase in enroute center facility and equipment investments and by a 2.21% increase in the facility and equipment costs of flight service stations. These additions are assumed to be in the form of conventional technology such as is represented in the facility and equipment replacement cost estimates for 1975 and 1979.

The FAA is currently considering a range of possible improvements to facilities and equipment in the air traffic control system. The facilities and equipment required for terminal area improvements are assigned a replacement cost of $1.1 billion for purposes of the stagflation scenario capital projections. Facilities, and equipment for enroute center improvements have been assigned a replacement cost of $448 million for the purposes of the stagflation capital projections. Improvements assumed for flight service stations total $541 million over the 1980's.

Beyond 1990, no comprehensive description of the FAA's capital programs has been discovered. Therefore, capital projections were based on assumptions about the rate of growth of total capital investment. Annual growth rates in facilities and equipment replacement costs from 1970 to 1980 have been fitted to a linear model, using time as the independent variable. The trend has been extrapolated through forecast period (1980-2020) and the annual growth rate at the mid-point of each decade was adopted as representative of the growth in ATC facilities and equipment investment during that decade.

The annual growth rates in total ATC facilities and equipment for the stagflation scenario, are as follows:

DECADE	ANNUAL RATE OF INCREASE
1990-2000	1.04932
2000-2010	1.03279
2010-2020	1.01627

The growth rates beyond 1990 for facilities and equipment in the terminal areas, the enroute centers, and the flight service stations have been assumed to bear the same relation to each other as they did in the period 1975 through 1979. That is, each percentage increase in terminal area facility and equipment replacement costs has been accompanied by a 0.89% increase in enroute center facility and equipment costs, and a 2.21% increase in flight service station facility and equipment costs.

The capital projections for both the balanced growth scenario and the rapid growth scenario differ from those of the stagflation scenario in two respects: (1) the balanced growth and rapid growth scenarios assume that a satellite-aided communication system will replace conventional navigation and communication technologies; (2) total investments in ATC facilities and equipment grows faster in the balanced growth scenarios than in the stagflation scenario.

For the balanced growth scenario it is assumed that conventional technologies are employed to the year 2000. The gradual replacement of conventional communication and navigational equipment with a satellite-aided system will occur from 2000-2010. By 2010 the replacement will be complete. The rate of capital consumption for the satellite-based technologies is more rapid than for conventional technologies.

Capital cost projections for the rapid growth scenario adopt the methods employed in the balanced growth scenario with two

modifications. (1) It has been assumed that the satellite-based communication and navigation system will replace conventional technology at a very early point in the rapid growth scenario. The satellite system is assumed to be fully implemented by the 2000. (2) The replacement costs of the ATC facilities and equipment will increase at a compound annual rate of approximately 109.3%. This rate is the product of the average compound increase in GNP assumed for the rapid growth scenario and the historical relationship of increases in F & E replacement costs to increase in GNP between 1972 and 1979.

For both the balanced growth scenario and the rapid growth scenario, growth rates for the terminal areas, en route centers and flight service stations are assumed to bear the same relationship to each other as they did in the stagflation scenario. That is, for each 1% increase in terminal area replacement costs, there is an increase of 0.89% in enroute center replacement costs and 2.21% for the flight service stations.

The primary impact of automation on labor is to add or delete personnel. Based on the FAA forecast and staff level projections, it has been concluded that the staff magnitude will increase with more aviation activity. Technological change will cause the center staff levels to grow at a slower rate than terminal staff. This is only so, however, if new technology is substituted for extant technology on a continuing basis. If the extant technology is

replaced with the same genre of equipment, one would expect labor utilization to be less efficient. Inefficient labor utilization would result in a staff growth rate proportional to activity levels.

In the stagflation scenario it is assumed that the agency capital to 2020 is based on extant technology. Therefore, while the level of capital may increase, such increase will be proportional to activity levels. It is anticipated that the number of terminal staff will increase from 15,540 to 17,696 in 2020 or 13.9%. The center workforce is expected to increase from 14,370 in 1990 to 21,924 in 2020, or 52.6%.

Under the balanced growth scenario, it is expected that terminal staff will increase with activity and center staff will decline. Centers will be more automated than terminals. The terminal staff is expected to increase from 17,062 in 1990 to 25,131 in 2020, or by 47.3%. Owing to automation the center staff is expected to decrease from 13,434 in 1990 to 4,071 in 2020 or by 69.7%.

Under the rapid growth scenario, terminal staff is expected to increase to accomodate growth and center staff is expected to decrease due to automation. It is anticipated that terminal staff will grow from 21,636 in 1990 to 31,147 in 2020 or 44.0% and center staff will diminish from 10,983 in 1990 to 2,172 in 2020 or 80.2%.

If stagflation investment occurs with balanced growth activity, then the terminal staff will increase from 19,512 in 1990 to 56,812

in 2020 or 191% and the center staff will increase from 18,812 in 1990 to 67,936 in 2020 or 261%. If the stagflation investment occurs with rapid growth activity, then the terminal staff will increase from 33,522 in 1990 to 138,112 in 2020 or 312% and the center staff will increase from 34,737 in 1990 to 245,218 in 2020 or 606%.

If balanced growth technology is in place and stagflation activity levels occur, the number of terminal staff will decrease from 13,503 in 1990 to 7,575 in 2020 or a decrease of 43.9%, and the number of center staff will decrease from 10,059 in 1990 to 1,200 in 2020, a change of 88.1%. If rapid growth scenario activity prevails, then the number of terminal staff will increase from 29,765 in 1990 to 62,647 in 2020, an increase of 110%, and center staff will decline from 25,981 in 1990 to 16,161 in 2020, a change of 37.8%.

If rapid growth technology is adopted and stagflation activity levels prevail, then terminal staff will decrease from 9,592 in 1990 to 3,541 in 2020, a change of 63.0%, and center staff levels will decrease from 3,945 in 1990 to 132 in 2020, a change of 96.7%. If balanced growth activity prevails in conjunction with rapid growth technology, then the terminal staff will decrease from 12,203 in 1990 to 12,166 in 2020, a change of 0.3%, and center staff levels will decline from 5,392 in 1990 to 490 in 2020, a change of 90.9%.

If stagflation technology and capital exists, then flight service personnel will increase from 4,714 in 1992 to 22,698 in 2020, an increase of 382%. If balanced growth activity occurs in conjunction with balanced growth technology, the number of flight service staff will decrease from 4,191 in 1992 to less than 100 in 2020. If rapid growth activity and technology previal, then the workforce is expected to increase from 1,690 in 1992 to 3,800 in 1996 and then decrease to 109 by 2020. If balanced growth technology is used with stagflation activity, the flight service station will be fully automated by 2003. If rapid growth technology is fully employed with either balanced growth or stagflation activity, the flight service stations could be fully automated by 1992.

The general trends in staff estimate data for congruent conditions are as follows:

(1) a general increase over time in the number of terminal staff for congruent conditions. The increase can be attributed to widespread growth and use.

(2) a general increase in center staff for stagflation, owing to the relative inefficiency of the extant technology and a decline in the center staff for balanced and rapid growth scenarios.

The terminal staff estimates of congruent conditions suggest that the extant technology is as efficient as the new technology until 2012. The optimum efficiency of the balanced growth and rapid growth technology does not occur until 2020. The stagflation scenario operations increase 11%, balanced growth 36%, and rapid

growth 48% between 2000 and 2020. Thus, the efficiency of the stagflation technology obtains only for low growth rates in operations. The relative inefficiency of new technology in terminal areas is due to the inherent constraints of airports. Excess or increased traffic can be accommodated by other airports in the terminal area.

The center staff estimates of congruent conditions indicate that the stagflation technology is inefficient when compared to the balanced growth and rapid growth technology. The operations measures for stagflation, balanced growth and rapid growth in 2000 are 2,714, 4,427 and 8,039 respectively. In 2020, the operations measures for stagflation, balanced growth, and rapid growth are 2,207, 16,681 and 49,938. In other words, in 2000, balanced growth operations are 63% greater than stagflation, and rapid growth operations are 196% greater than stagflation. In 2020, balanced growth operations are 655% greater than staflation and rapid growth operations are 2,160% greater than stagflation.

The purpose of the non-congruent level estimates is to examine the marginal changes in staff for fixed capital investment of one sort and variations in activity levels.

If balanced growth activity occurs using stagflation capital the relative productivity declines. The operations per terminal staff decrease from 6,023 to 3,489 in 2000, from 6,382 to 2,652 in 2010, and from 6,270 to 1,953 in 2020. Center productivity decreases from 2,714 to 1,484 in 2000, from 2,369 to 956 in 2010, and from

2,209 to 717 in 2020. If rapid growth activity occurs, then terminal productivity also deteriorates from 6,023 to 1,802 in 2000, from 6,382 to 1,240 in 2010 and from 6,270 to 803 in 2020. Center productivity deteriorates from 2,714 to 669 in 2000, from 2,369 to 347 in 2010, and from 2,209 to 198 in 2020. It can be concluded that continued investment in extant technology will not effectively accommodate reasonable growth in aviation activity. As such, the capital investment strategy for stagflation should not be pursued beyond 1990.

If balanced growth technology is in use and stagflation activity occurs, then the terminal productivity will increase from 5,295 to 9,283 in 2000, from 5,524 to 13,623 in 2010, and from 6,564 to 21,776 in 2020. Center productivity will increase from 4,427 to 8,469 in 2000, from 8,165 to 21,646 in 2010, and from 16,681 to 56,218 in 2020. If rapid growth activity occurs with balanced growth technology, then terminal productivity will decrease from 5,295 to 2,685 in 2000, from 5,524 to 2,528 in 2010, and from 6,564 to 2,640 in 2020. Center productivity will diminish from 4,427 to 1,883 in 2000, from 8,165 to 2,754 in 2010, and from 16,681 to 4,202 in 2020.

Rapid growth technology will be the most efficient with respect to other scenario activity. In other words, rapid growth technology employed in conjunction with stagflation or balanced growth activity will increase system productivity. If stagflation activity occurs with rapid growth technology, then terminal productivity increases

from 5,476 to 19,631 in 2000, from 6,048 to 34,237 in 2010, and from 7,149 to 62,888 in 2020. Center productivity increases from 8,039 to 40,779 in 2000, from 19,170 to 177,792 in 2010, and from 49,938 to 821,606 in 2020. If balanced growth activity occurs with rapid growth technology, then terminal staff increases from 5,476 to 11,017 in 2000, from 6,048 to 13,521 in 2010, and from 7,149 to 18,304 in 2020. Center productivity increases from 8,039 to 20,238 in 2000, from 19,170 to 62,006 in 2010, and from 49,938 to 221,330 in 2020.

It is anticipated that both terminal and enroute activity will increase under the three socioeconomic scenarios. It is, therefore, reasonable to assume that the message load will increase with shifts in activity level. The differences among scenarios will be the communication magnitude, as well as the extent to which messages are automated.

In the stagflation scenario, the communications load in terminal areas will change as follows between 1992 and 2020. Total messages will increase by 119 million; advisory communications will increase by 7 million; vector communications will increase by 14 million, altitude instructions will increase by 33 million; speed control instructions will increase by 4 million; miscellaneous communications will increase by 33 million; beacon assignment communications will increase by 7 million; and radar contact communications are expected to increase by 9 million. Changes for enroute center

areas in the stagflation scenario between 1992 and 2020 are as follows. Total messages are expected to increase by 56 million which includes a 3 million increase in advisory communications; a 9 million increase in vector communications; a 14 million increase in altitude instructions; a 9 million increase in speed control instructions; a 4 million increase in miscellaneous communications; a 9 million increase in beacon assignment communications; and a 9 million increase in radar contact communications.

Changes in the communications load for terminal areas in the balanced growth scenario between 1992 and 2020 will be as follows. Total messages are projected to increase by 382 million. This will include a 21 million increase in advisory communications; a 78 million increase in vector communications; a 109 million increase in altitude instructions; a 12 million increase in speed control instructions, a 107 million increase in miscellaneous communications; a 21 million increase in beacon assignment communications; and a 27 million increase in radar contact communications. For enroute center areas in the balanced growth scenario total messages are expected to increase by 164 million between 1992 and 2020. Advisory communications will increase by 9 million; vector communications will increase by 25 million; altitude instructions will increase by 43 million; speed control instructions will increase by 25 million; miscellaneous communications will increase by 12 million; beacon assignment communications will increase by 25 million; and radar contact communications will increase by 25 million.

Total messages are projected to increase by 598 million between 1992 and 2020 for terminal areas in the rapid growth scenario. Advisory communications will increase by 32 million; vector communications will increase by 121 million; altitude instructions will increase by 170 million; speed control instruction will increase by 18 million; miscellaneous communications will increase by 167 million; beacon assignment communications will increase by 32 million; and radar contact communications will increase by 43 million. For en route center areas in the rapid growth scenario total messages are expected to increase by 327 million between 1992 and 2020. This increase includes a 16 million increase in advisory communications; a 51 million increase in vector instructions; an 84 million increase in altitude instructions; a 51 million increase in speed control instructions; a 23 million increase in miscellaneous communications; a 51 million increase in beacon assignment communications; and a 51 million increase in radar contact communications.

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